SELECTION OF APPROPRIATE LEVEL OF TECHNOLOGY FOR THE CONCRETE BLOCK INDUSTRY

A THESIS

Presented to

The Faculty of the Division of Graduate Studies

By

Jose Luis Sanchez Garza

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

in the School of

Industrial and Systems Engineering

Georgia Institute of Technology

June, 1978

SELECTION OF APPROPRIATE LEVEL OF TECHNOLOGY FOR THE

CONCRETE BLOCK INDUSTRY

Approved:

David E. Fyffe, Chairman

Thomas B. Clark

Joseph Krol

Date Approved by Chairman MAY 30, 1978

ACKNOWLEDGEMENTS

I wish to express my true appreciation to Dr. David E. Fyffe, my Thesis Advisor, for his encouragement, concern, and wise guidance throughout the stages of my work.

Special thanks are also due to Dr. Joseph Krol and Dr. Thomas B. Clark for participating in my Reading Committee providing valuable, constructive criticism for the achievement of my Thesis' objectives.

I like to thank sincerely the Concrete Block Manufacturers, and Concrete Block Equipment Manufacturers who collaborated with my work providing data which was indispensable for the validity of the study. I also thank the National Masonry Association for his invitation to participate in their Annual Exposition held in Atlanta, Ga., February 1978.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (continued)

LIST OF ILLUSTRATIONS (continued)

CHAPTER I

INTRODUCTION

Appropriate Technology

Statement of the Problem

Since the Industrial Revolution started there have been tremendous advances in the world's technology. Manufacturing processes that years ago took dozens of men and many weeks to be accomplished, at present can be done with a crew of few men and in only a few days thanks to the machinery, equipment, and materials that technological advances have brought about.

Modern technology has been developed mainly in highly industrialized countries and through the years their industries have changed from labor-intensive to capital-intensive. The consequent increase in productivity of capital and labor and the better utilization of materials has resulted in great economic development of these nations. On the other hand, developing countries face the problems of poor economic development due to the technology gap between them and industrialized countries.

Developing nations have tried to supply the desparity of technology by transfering new technologies from developed countries. It is a fact that much of their industrial technology has been imported, and that their domestic infrastructure has been heavily influenced by technology transfer. Whether the imported technologies are "appropriate" or not is an important issue because the environments of the developing countries differ from industrialized countries in many important aspects such as availability and quality of the factors of production (i.e., capital and labor; raw materials; physical environment and climate; market size and concentration; necessary quality standard; and the general level of social and economic development). (62, p.78) It is these differences which may make a technology inappropriate in a developing country.

Literature Survey

In their effort toward industrialization, developing countries face a number of problems. The department of Economic and Social Affairs of the United Nations in its report "Appropriate Technology and Research for Industrial Development," stated in 1972 about developing countries that (81, p. 4):

> While they mostly have substantial untapped natural resources, they suffer from shortages of capital and particularly of foreign exchange, as well as technical and managerial skills. The situation is further complicated by other factors, including climatic conditions, the size of their market and the characteristics of local raw materials. Moreover, most developing countries have increasingly serious problems of unemployment and under-employment, aggravated by the rapid growth of the labour force and rural-urban migration..........developing countries are faced with selecting industries and technologies which take account of all the problems mentioned above.

In general, developing countries are characterized by having a relative lack of capital resources and a relative abundance of labor (i.e., high cost of capital and low cost of labor), while rich capital resources and specialized labor characterize developed countries (i.e., low cost of capital and high cost of labor). The capital-intensive technologies developed by industrialized countries for their own environment are said to be inappropriate for the labor-intensive environment of developing countries.

Appropriate technology has been defined as......"any manufacturing technology based on modern science which is in harmony with its environment." (75) There are many lists of the characteristics of appropriate technology prepared by different organizations and individuals. Those which are generally accepted have been stated by Hammond in his paper "Appropriate Technology Research at Georgia Tech and the Small Industry Development Network." (31, p. 20)

1. Technology is seldom directly transferable. More often than not it must be adapted to different environmental conditions....

2. The various cultural, political, economic, and infrastructure conditions must be considered in suggesting the appropriate technology....

3. To the maximum extent possible, local materials and natural man-power, and man-made resources should be utilized (foreign imports usually are high in cost and foreign exchange in short supply).

4. Appropriate technology should encourage and foster indigenous initiative and innovation. It is not sufficient to buy technology and know-how and to transfer and install it without encouraging in the productive system flexibility and willingness to change with changing markets and other factors.

5. Appropriate technologies must have or develop logistical support systems, such as maintenance services and spare parts availability.

6. Basic to intermediate technology is the concept of cost effectiveness. Hence, most considerations of intermediate technology are concerned with labor-intensive, low-cost elements.

Developing countries need to select from available technologies the appropriate technology which is best suited to their structures of resources and needs. These nations need to develop a technology which is not capital-intensive, yet it has capabilities of quality and rate of production; which does not have the characteristics of handicraft labor-intensive technology, yet it requires almost as much labor. Such new industrial technologies, would be both modern and appropriate. Staley and Morse (76) state that it would be wrong to suggest that the proper approach to develop an appropriate technology is simply to look backward in the technological history of the more developed countries and follow the same pattern. Basic science and technology have progressed in the meantime and this progress must be used to incorporate improvements in the technological development of new industrializing nations. The term appropriate technology might be interpreted, wrongly, to mean that the latest or new techniques are "too good" for the new developing countries and that they should accept something "inferior." In many fields further inventions are needed; new equipment design, for example, which are specially tailored to capital-scarce, labor-intensive, small-market, climatic, infrastructural conditions of developing countries. Stepanek (73) and Gadgil (26) in their paper presented at the meeting of working group held at the Small Industry Extension Training Institute, Hyderabad, 1967, mentioned that new industrial technologies, which would be both modern and appropriate, can be developed by 1) starting with traditional methods and using modern knowledge to improve on them; 2) starting with the modern methods of the highly developed countries and adapting them to the conditions of newly developing countries; and 3) analyzing the technological problems of the newly developing countries directly, to come up with new approaches through fresh research and development. Also, the import by new industrializing countries of partially or wholly reconditioned equipment and plants which have become obsolete in high-wage countries solely or mainly because they use too much labor, should be considered in the selection of technology (82).

It should be recognized that whenever technological alternatives are available, industries with labor-intensive technologies, or industries in which different combination of labor and capital exist side by side will be selected in order to alleviate unemployment. However, there are cases in which technological alternatives are not available, and where, if a particular industry is to be established at all, there is no other choice than to adopt a technology even though it may be capital-intensive technology which employs relatively little labor.

> Appropriate choices of industrial technologies in developing countries requires selecting those technologies which produce, in an optimum manner, the kind, quality and uniformity of products suitable for the requirements of local and export markets, with the lowest possible utilization of capital and skill and the highest possible use of labor and materials avaialble locally (81, p. 7).

The choice of appropriate technology involves not only the requirements of a given situation, but should also take account of long-term perspectives. When using capital-saving techniques, a country should be careful not to perpetuate stagnation. Saburo stated in 1974 that whereas in a labor-intensive industry large total wage payments to many workers are involved, payments in a capital-intensive go largely to a relative small number of individual owners in the form of dividends, interest and rents. In the former case there is a high propensity of workers to consume the wage on the necessities of life and thus save very little, if any, but high levels of productivity in the latter, capital-intensive case, results in the accumulation of a surplus which is then available for further investment. Assuming that it is invested productively, in the long run this approach should result in more output, more growth, and more employment (56). Thus, there is a trade-off analysis required to determine to what extent labor-intensive technologies are desired, or labor-saving technologies must be avoided.

Despite the above arguments, capital-intensive technologies are still purchased and utilized in developing countries. Probably the most important reason is that inappropriate technologies from developed countries do exist, are available, and do work-even if inappropriately. (62) Many industries in developing countries often result from a contract with private foreign companies, involving agreements on direct investment and transfer of technology. In most cases developing countries are not able to influence the type of technology utilized by the foreign investors. Another reason is that companies which supply technical know-how will seldom worry about the "appropriateness" of the technologies to the conditions of the developing country. Firms supplying technology and equipment sometimes find it risky to spend their money on the development of a special technique or equipment for a given developing country as they are not sure of recovering the investment. As a result, such firms usually supply technologies or equipment which are available but not necessarily appropriate to the conditions of a particular developing country (81). It is also true that equipment salesman sometimes tend to offer to developing countries the most expensive models. It is true, of course, that suppliers sometimes adapt technology in transfer to developing countries, but they do so only under rather special circumstances; this varies from one industry to another. Finally it must be pointed out that many developing countries do not have a plan for research and development to find their appropriate technology. The reason for this is perhaps that R and D involves a great investment and scarcity of capital makes it impossible, or because they disregard the seriousness of the problem. In either case the consequences are that inappropriate technologies prevail while social, political, and economic development of those nations continues to be slow and aggravating their situation.

Richard S. Eckaus in its book "Appropriate Technologies for Developing Countries" discusses the alternative criteria of appropriateness of technological decisions. Eckaus states that the only standard for deciding the appropriateness of technological decisions is reference to the general goals of development:

> The qualities of technology are not more or less desirable in themselves but only of their output potential, their corresponding input requirements, and their effects on social and political organization. In particular, small-scale or labor-intensive technologies are not necessarily "appropriate" because they are small scale or labor-intensive. Whether they are appropriate depends on their ability to contribute to development objectives (22, p. 37).

The most common criteria for appropriateness of technological decisions as goals for development in a country are maximization of net national output and income, maximization of availability of consumption goods, maximization of rate of economic growth, reduction of unemployment, redistribution of income and wealth, regional development, balance of payments relief, and improvement in "quality of life." These criteria must be judged and adopted as required for decision-makers responsible for technological decisions of a country.

Point of View of This Research

In this research "appropriate technology" is discussed from the point of view of a private institution, i.e., maximizing output with a minimum input. This point of view is much simpler than that of national policy for development, discussed above, which takes into account social, economic and political aspects. However, the same principles of economics and development apply also to private institutions in the sense that it also needs to select a technology which best suits local and export requirements, at the lowest possible cost. In fact, national development is achieved through encouraging development of private institutions.

Appropriate choice of manufacturing technologies require selecting methods and equipment which produce, in an optimum manner, the kind, quality, and uniformity of products suitable for the requirements of local and export markets, at the lowest possible cost.

Objective of the Study

The objective of this study is to provide information about the available methods and technologies for the manufacture of concrete blocks, and to develop a methodology to select the most appropriate technology level for the concrete block industry. The overall objective of the study can be divided in three sub-objectives:

1. To identify and explain current available technologies for the stages of the concrete block manufacturing process. This part of the study includes an explanation of each operation of the stages of the process, which in addition of setting a ground for the other two sub-objectives, it also intends to help engineers and designers arriving to new ieas to develop a technology specially designed for the structures of resources and needs of developing countries.

2. Provide data on initial cost, capacity, labor requirements, and power and fuel consumption for each of the identified technologies.

3. Based on points one and two, develop and demonstrate a methodology of evaluation and selection of the appropriate technology level for a given production output and specified capital and labor cost.

The results permit an enterpreneur to select technological alternatives which will result in lowest cost per unit when cost of labor and capital are specified.

The use of concrete block is worldwide for it is safe, durable, and inexpensive building material, which also works as insulator offering comfortable living conditions. These characteristics make concrete block a suitable building material in developing countries. Consequently, the transfer of technology from industrialized countries to developing countries is substantial and there is a need to identify and evaluate currently available technologies and to select the appropriate technology level to be adopted or developed in a particular country.

Approach, Scope and Limitations

The objective of the study was accomplished as follows:

In order to identify the available technologies the concrete block manufacturing process was analyzed by visiting and/or contacting block manufacturers and equipment manufacturers. Four stages in the manufacturing process were found:

Materials handling and concrete making,
Forming the block,
Handling the block, and
Curing.

An overview of the process is presented in Chapter II discussing the highlights of each stage and providing a process chart diagram for a better illustration.

Subsequently, Chapter III, IV, and V deal with the description of each stage of the process (block forming and handling, curing, and materials handling and concrete making, respectively) analyzing each operation and identifying the available equipment for each stage. The equipment is then classified into technology levels ranging from highly automatic, sophisticated technologies, to rustic manual technologies, (i.e., capital-intensive to labor-intensive technologies). Subsequently each technology level is discussed separately. The equipment classified under each technology level is described explaining how it works throughout the manufacturing process. The discussion provides general information on the functioning of equipment, amount of labor as well as skills required for its operation, power and fuel requirements, capabilities regarding the quality and rate of production obtained with each type of equipment, and some notes on maintenance requirements. With this background and based on brackets of output requirements specific data on initial cost, labor requirements, and power and fuel consumption were estimated for each technology under the classification.

These chapters provide a classification and description of the available methods and technologies in order to distinguish several levels of capital and labor intensity. The analysis does not attempt to cover technical aspects of machinery and equipment. In the same way the technology of materials and the thermodynamics of curing treatments are beyond the scope of this study. Regarding the data on costs, labor, and power and fuel, as stressed in each chapter, they are estimations based on the characteristics of equipment classified under the same technology. Despite of the fact that these data was obtained from relaiable sources and estimations made consciously, they should not be used to make the final evaluation of a particular project. The data is useful to obtain good estimations of the cost of the factors of production, and have an idea of the economic effectiveness of several technologies.

Finally in Chapter VI an example is worked out to develop, based on data provided, a methodology of evaluation and selection of the appropriate level of technology for a given production output and specified capital and labor cost. The appropriateness of a technology is based for our purposes in the minimum unit manufacturing cost. The evaluation does not involve social or political aspects.

By following the suggested methodology of evaluation and selection, the technology which results in lowest manufacturing cost to produce block of a given capacity can be chosen.

It should be pointed out that this study does not involve a technological forecasting analysis nor a costs trend analysis. It is a fact that a technology which is appropriate today can turn out to be inappropriate after some years because of a change in the cost of equipment, labor, or energy. This limitation should be taken into account before the final decision of the technology to be adopted is made.

CHAPTER II

AN OVERVIEW OF THE CONCRETE BLOCK PRODUCTION PROCESS

The concrete block process begins with the preparation of the concrete from raw materials (aggregates, cement, and water), and ends with the blocks stacked in the yard ready for delivery.

There are four stages in the process:

I) Raw Materials Handling and Making the Concrete,
II) Block Forming,
III) Block Handling (Green and Cured Blocks), and
IV) Curing.

Figure 2-1 depicts the sequence of these stages in the process.

For a better understanding of the process, each one of its stages has been broken down into operations and presented as a flow process chart in Figure 2-2. The numbers on the chart are explained below and grouped under their corresponding production stages.

I) Raw Materials Handling and Making the Concrete

Aggregates:
1. In-process storage*
2. Convey materials to batching
3. Batching
4. Convey batches to mixer

Cement:
1. In-process storage*
2. Convey material to batching
3. Batching
4. Convey batches to mixer

*Not operations, they indicate the position of materials or blocks while in-process. Materials or blocks in-process storage

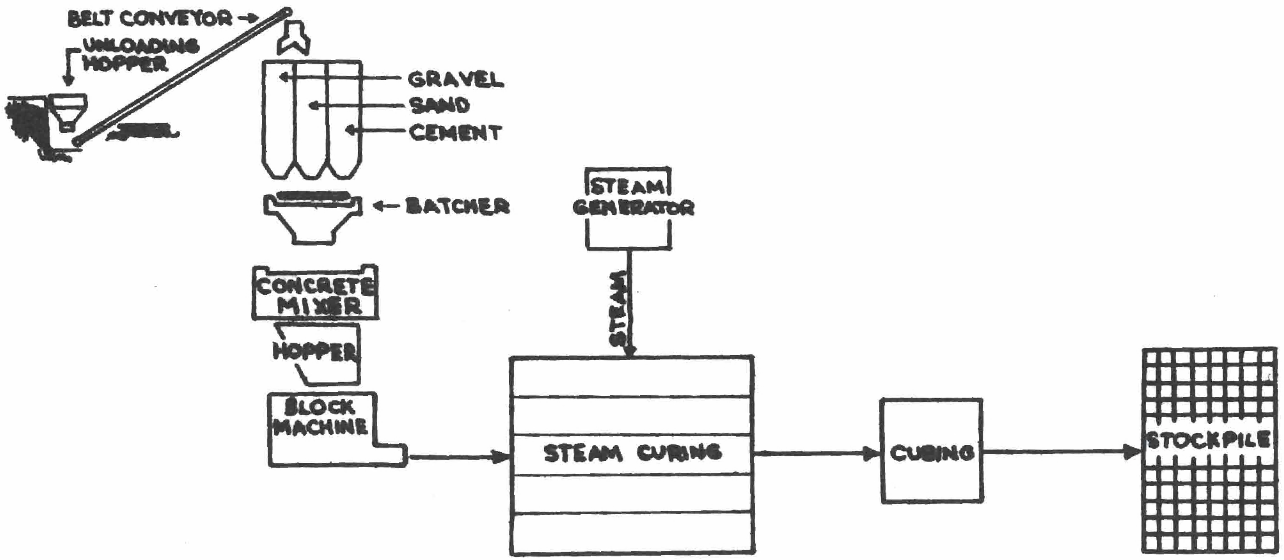


Figure 2-1. Sequence of the Block Manufacturing Process

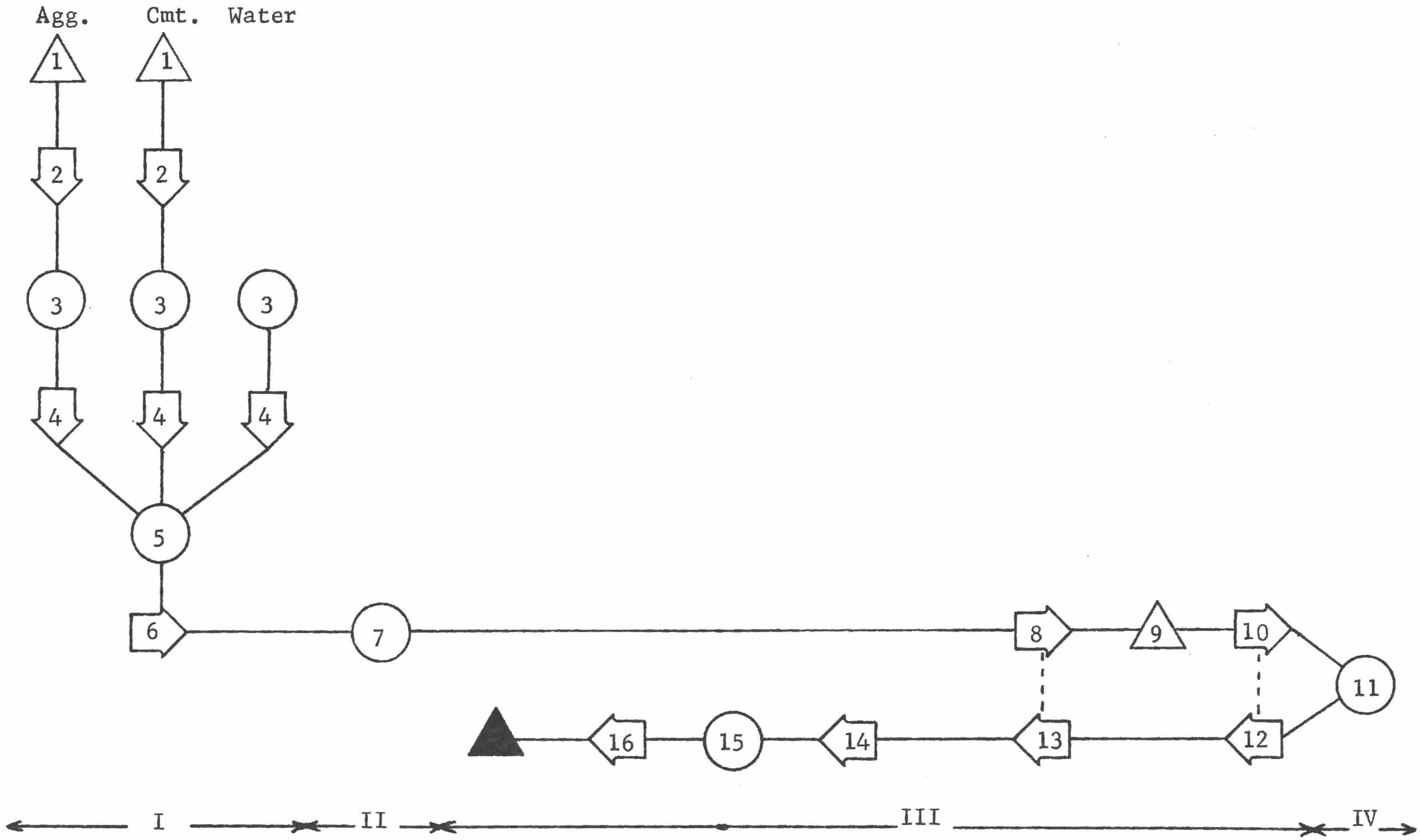


Figure 2-2. Flow Process Chart

Water:
3. Proportioning
4. Convey to mixer

Aggregates, cement, and water:
5. Mixing
6. Convey mix to forming machine

II) Block Forming

7. Forming operation

III) Block Handling

8. Offbear block from machine and load in-process storage device
9. In-process storage*
10. Convey to curing
12. Retire from curing
13. Unload in-process storage device
14. Depalletizing and feeding pallets into machine
15. Cubing
16. Yarding cubed blocks

IV) Curing

11. Curing operation

Handling Operations 8 and 13, and 10 and 12 are connected with a dotted line indicating a direct relationship between them. Operations 12 and 13 are the reverse of Operations 10 and 8 respectively. Consequently, the equipment used to carry out Operation 12 will be either the same or a similar to that used to accomplish Operation 10. The same is true of Operations 13 and 8.

Stage I: Raw Materials Handling and Concrete Making

The concrete block process starts out with the handling of raw materials and their proportioning and mixing to make the concrete. This

*Not operations, they indicate the position of materials or blocks while in-process. Materials or blocks in-process storage.

stage begins when materials, aggregates, and cement are received from suppliers and ends when the concrete is deposited into the forming machine.

The selection of block aggregates is an important factor to be controlled. The important characteristics of aggregates are cleanness, durability, and grading. Careful attention to the details of handling the aggregate is necessary for production of a uniform block. Aggregates are stored either in silos or piled on the ground. Different aggregate should never be stored together. Cement is stored either in silos when it is supplied as bulk cement, or in a storage room when it is supplied in sacks.

To make the concrete, aggregates, cement, and water are proportioned and mixed together. Obtaining the right proportions of aggregates, cement, and water is an important part of the process. Proportions of materials determine the strength of the block and consequently its quality. Improper proportions yield crumbly blocks with inadequate strength. The proportions are expressed as one part of cement to a number of parts of fine aggregates and a number of parts of coarse aggregate; the ratio water/cement shall be taken into account when designing the mix also. Anyone trying to design a mixture should study about the matter. Several references are provided in this paper for that purpose.

There are two ways to measure the proportions of aggregates and cement, by weight and by volume. Proportioning by volume produces good concrete if the workers are skillfull; however, some block characteristics such as color, strength, weight, and uniformity are difficult to achieve. The water can be proportioned by volume (based on a water/cement ratio) and added to the materials in its due turn, or it can be added directly to the mixer to obtain the desired thickness of the mixture. When the desired thickness is reached the water valve is automatically closed.

Mixing is as important as proportioning. The ideal mix is to have every particle of aggregate coated with a film of cement paste. It is possible to achieve this with hand-mixing if the correct method is observed; however, it is more easily achieved by machine mixing.

Stage II: Block Forming

Once the mix is ready it is conveyed to the blockforming machine. In the complete process of block production the actual forming of the block in the machine (from filling the mold to ejection of the block) is often the shortest stage. However, this stage is the core of the process since it is at this point that the materials are transformed into blocks.

In the block forming stage concrete is deposited in a mold and the block is formed by tamping, vibration or a combination of vibration and compression depending on the type of machine. After molding the units are stripped immediately from their molds so that they rest on plain, flat pallets. Freshly molded blocks have sufficient strength to retain their shape without benefit of molds. In the next chapter the operation of different types of machines currently available are discussed.

A distinguishing feature in the manufacture of concrete block is the no-slump, nonplastic concrete used. Nonplastic by normal standards, the concrete becomes plastic momentarily during the molding due to the intensive tamping, vibration, or vibration and compression applied.

Stage III. Block Handling

The block handling stage includes both green block handling and cured block handling. The curing of the block takes place between these two sub-stages.

Green block handling consists of two handling operations and one in-process storage as follows (see Figure 2-2):

8 Offbear* block from forming machine and load the in-process storage rack,

9 In-Process storage rack,

10 Convey block to curing area.

The freshly formed block on its pallet is offbeared and taken to the curing area remaining there temporarily on racks until it reaches a desired strength. At this point, the blocks (which are now cured or partially cured) enter the cured block handling sub-stage.

Cured block handling is composed of four handling operations, and one packing or cubing operation as follows (see Figure 2-2):

12 Retire block from curing area (Kilns),

13 Unload in-process storage,

14 Depalletizing and feeding pallets into forming machine,

15 Cubing operation, and

16 Yarding cubed blocks.

After curing the blocks we do not need the pallets any longer. The pallets are reused, and the blocks are cubed to complete the hardening or to be delivered.

The productivity of the forming machines, and in general of the plant, is determine to a great extent by block handling capacity. The

*Offbear is a common term used in the masonry industry meaning the action of carrying freshly made units off the forming machine.

various types of block handling equipment and their operations are discussed fully in Chapter III.

Stage IV: Curing

The curing of the blocks is an important stage of the process. At this stage the blocks are submitted to a treatment to reach the strength necessary to be used. The natural way of curing blocks consists in laying the pallets of block on the ground and letting the concrete to harden for two or three days; after this previous hardening the blocks can be stripped from their pallets and cubed to be yarded. The hardening process of the concrete continues and after 26 days the blocks reach the strength necessary to be used. The hardening period can be reduced to fifteen days by using early strength cement.

There are other two treatments to cure the concrete block, there are low-pressure steam and high-pressure steam curing or autoclaving. In the first case the green blocks are placed in a kiln and steamed at atmospheric pressure and temperature of about 150°F. After a period which varies from 10 to 24 hours, the blocks are taken out of the kilns to be cubed and carried to the yard. The blocks remain in the yard for seven days to complete hardening.

In the case of high-pressure steam curing the process is different. The blocks are placed in an autoclave* and steam is injected into it at high pressure (500 psi) and temperature (200°F). The curing period varies from 10 to 24 hours; during this period hardening is thoroughly completed. In Chapter IV each curing treatment is discussed in detail.

*Autoclave: It is a pressure vessel for injection of steam at high pressure and temperatures.

CHAPTER III

TECHNOLOGICAL ALTERNATIVES FOR BLOCK FORMING AND BLOCK HANDLING

The overview of the concrete block production process presented in Chapter II identified four major stages: raw material handling and making the concrete, block forming, block handling, and curing. The technological choices for the second step, block forming, will, to a large extent, dictate the choice of the level of technology for each of the other steps. If, for example, block forming is done by fully automatic equipment, manual mixing and handling are infeasible. Likewise, if block forming is done manually, automated materials handling, block handling, and curing are infeasible. For this reason, it is desirable to first discuss in detail the block forming operation and to classify the many types of equipment that are currently available. For each type of equipment, estimates are made of both capital costs and operating costs.

Stage II. Block Forming

The block forming process has evolved from making blocks manually with a wood or metal mold, where concrete is manually tamped, to fully automatic, high-speed machines which form blocks by vibration and compression of the concrete. A crew of six men can produce about 400 blocks per eight-hour shift manually while up to 23,000 blocks per shift can be produced by five men using automatic block-making equipment.

In order to avoid individual cost analysis, the various block forming machines which are currently available are classified into four categories of decreasing technology. These categories are as follows:

Automatic,
Semi-Automatic,
Manually Operated, Powered,
Manual Blockforming Machines.

Automatic Blockforming Machines

Automatic blockforming machines are the most important group within the classification. Because of their performance and wide variety of sizes and brands, they are now widely used.

These machines can work either continuously or intermittently. Continuous automatic operation requires only that an operator activates the machine at the beginning of the shift and attend any malfunction. An automatic forming machine can be operated continuously only if the block handling equipment, mainly the offbearing equipment, can handle the output at the same rate that the machine produces.

To make the block, the hopper on top of the machine is filled with concrete and the pallet magazine loaded with pallets. When the machine is switched on it continues to produce blocks delivering them onto a roller conveyor. If the block handling equipment cannot keep up with a continuous production, the machine has to be operated intermittently; otherwise the blocks jam and the production becomes impossible. Intermittent operation requires that the operator depress a button every cycle. When the machine is activated it delivers one or two pallets of block (as previously programmed) and stops until it is activated again.

In all machines, forming of the block is achieved by vibration and compression of the concrete. Automatic forming machines are mainly of two types: hydraulic and cam driven. The blocks produced have the same quality regardless of the type of machine.

Since there are many blockforming machine manufacturers, there are many brands of machines offering a wide variety of sizes and capacities. Figure 3-1 to Figure 3-8 show some examples of automatic machines of different sizes.

In this study automatic forming machines have been classified according to output capacity. Table 3-1 shows this classification presenting eight types of forming machines for capacities ranging from 23,000 to 2,000 standard blocks per eight-hour shift. In this table an estimation of the initial cost for each type of machine is given. The estimates are based on information from manufacturers and represent an average initial cost for each machine type.

Table 3-1 also shows estimates of the total horsepower for each type of machine. These figures are an average of the horsepower installed in several machines classified under the same type or capacity. These machines usually need 220/440 volts, 3 phase, 50 or 60 cycles to be driven.

Automatic forming machines are operated by one man if intermittent operation is adopted, and require only a fraction of a man's time if operated continuously.

These machines are rugged, well-built, and designed to be easily maintained. Under normal circumstances and proper maintenance a machine can work as long as 15 years without any trouble. There are many

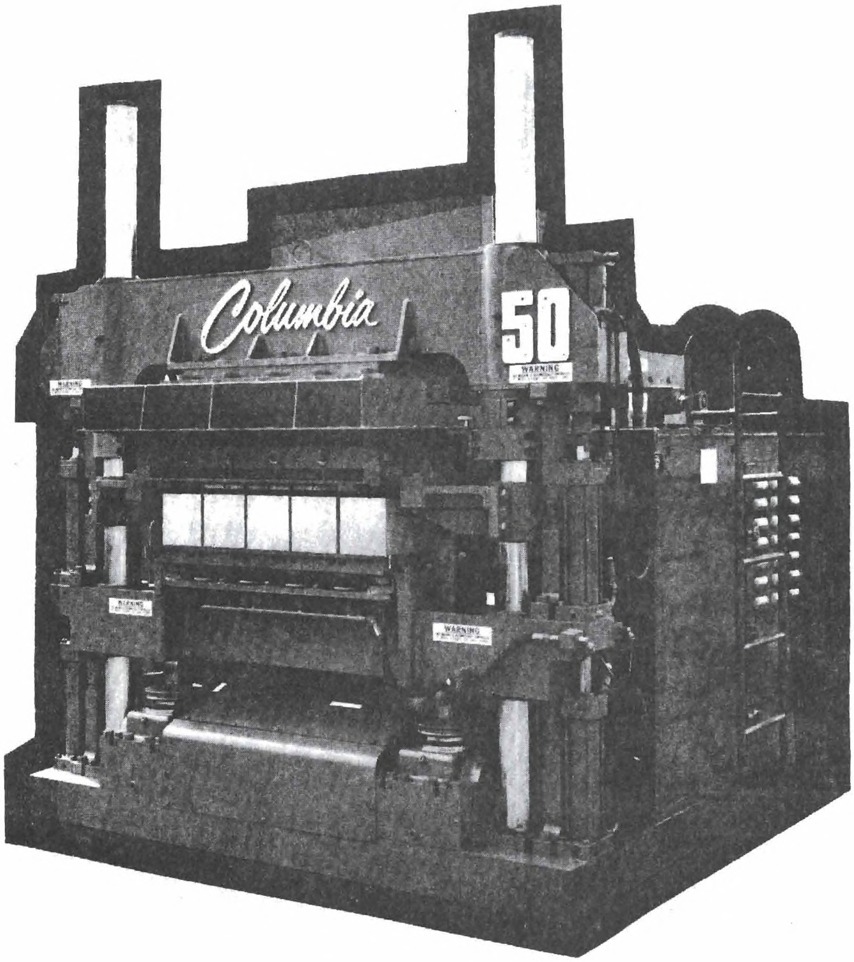


Figure 3-1. Automatic Blockmaking Machine
Equivalent to Machine 2 in Table 3-1

Picture Courtesy of Columbia Machine, Inc.

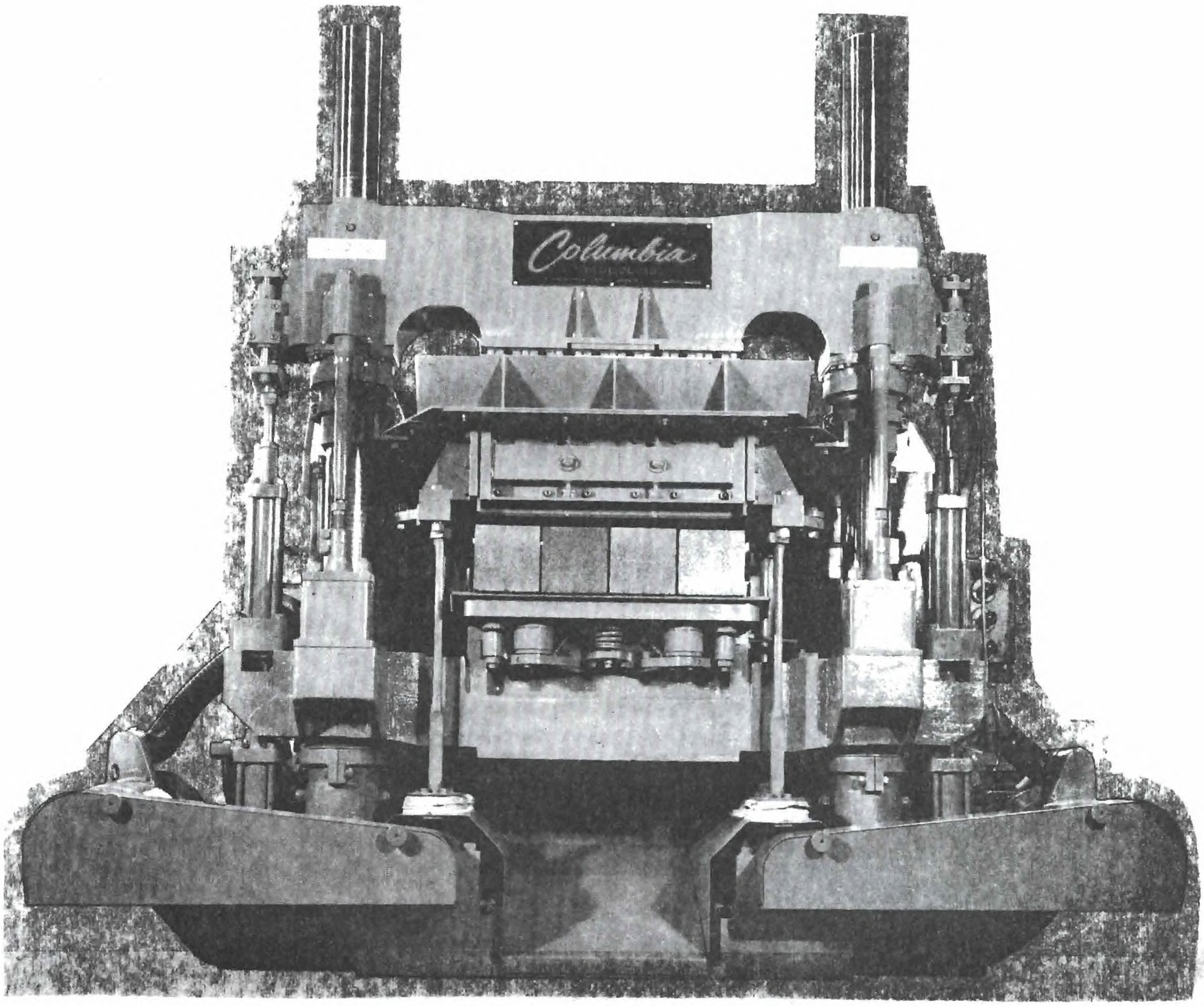
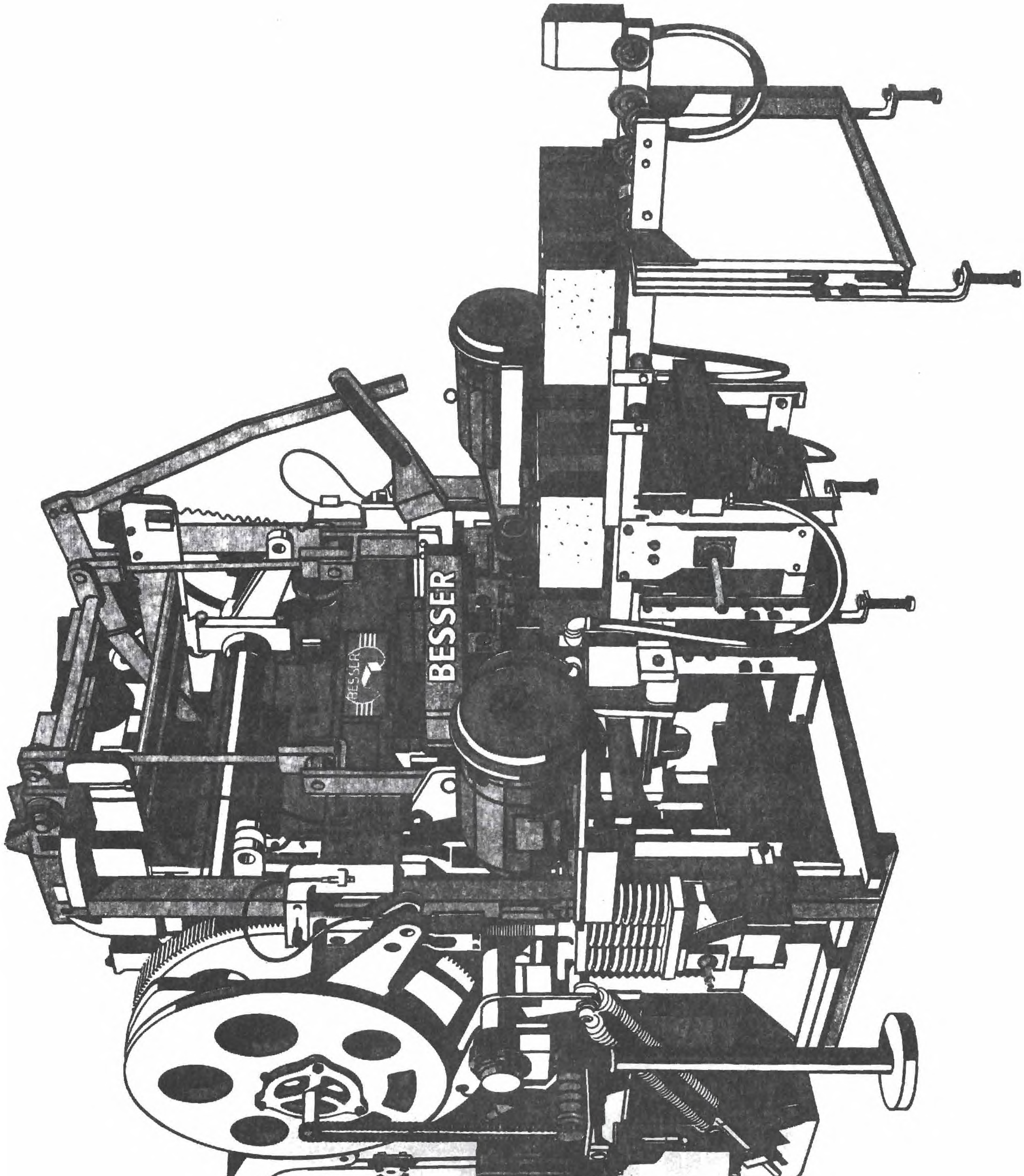


Figure 3-2. Automatic Blockmaking Machine
Equivalent to Machine 3 in Table 3-1

Picture Courtesy of Columbina Machine, Inc.

Figure 3-3. Automatic Blockmaking Machine
Equivalent to Machine 4 in Table 3-1

Picture Courtesy of Besser Co., Alpena, Mich.


BESSER

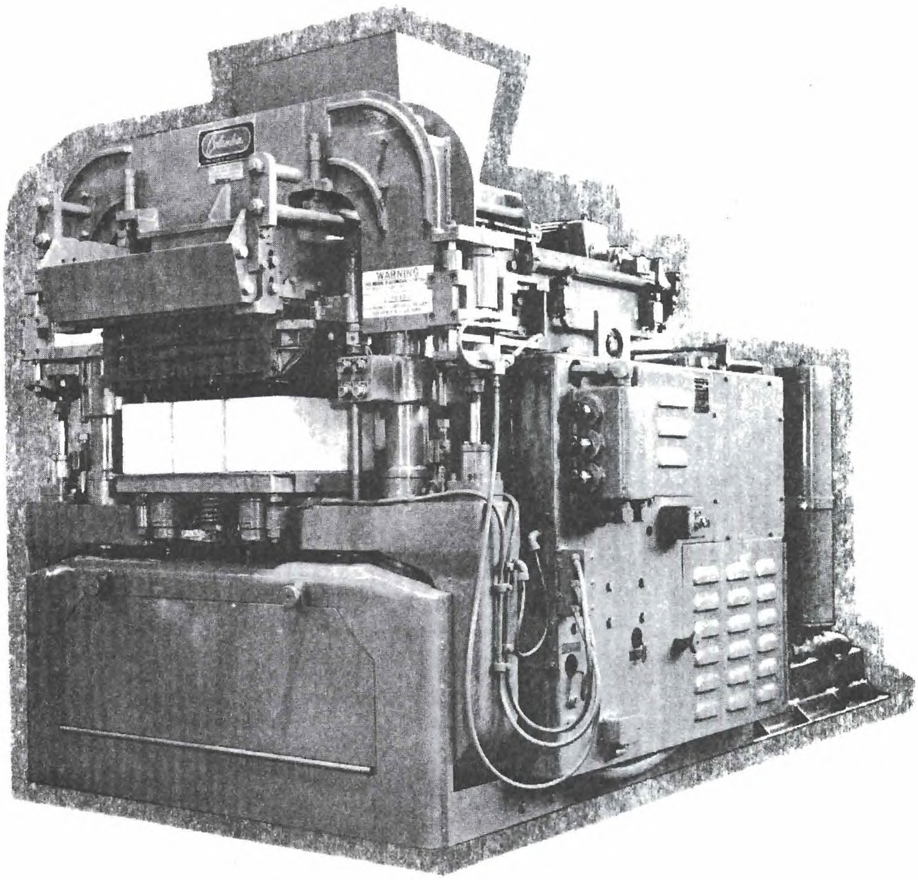


Figure 3-4. Automatic Blockmaking Machine
Equivalent to Machine 5 in Table 3-1

Picture Courtesy of Columbia Machine, Inc.

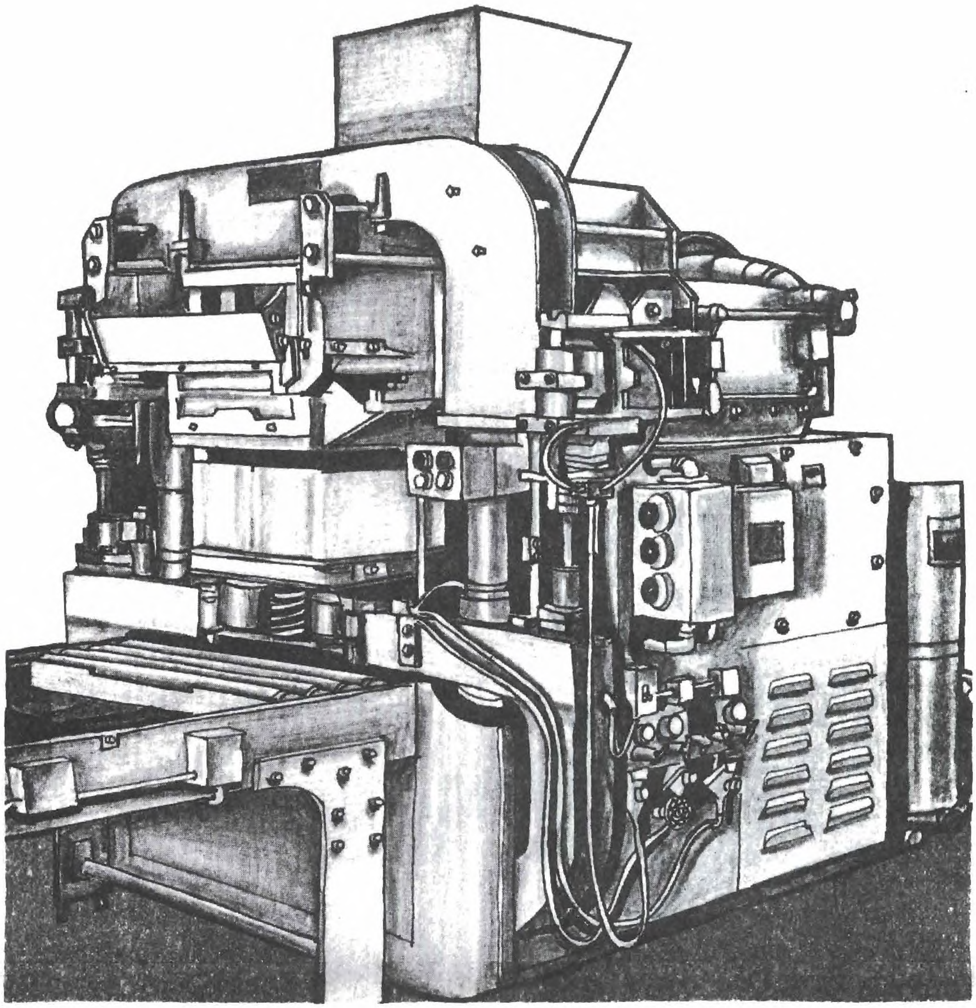
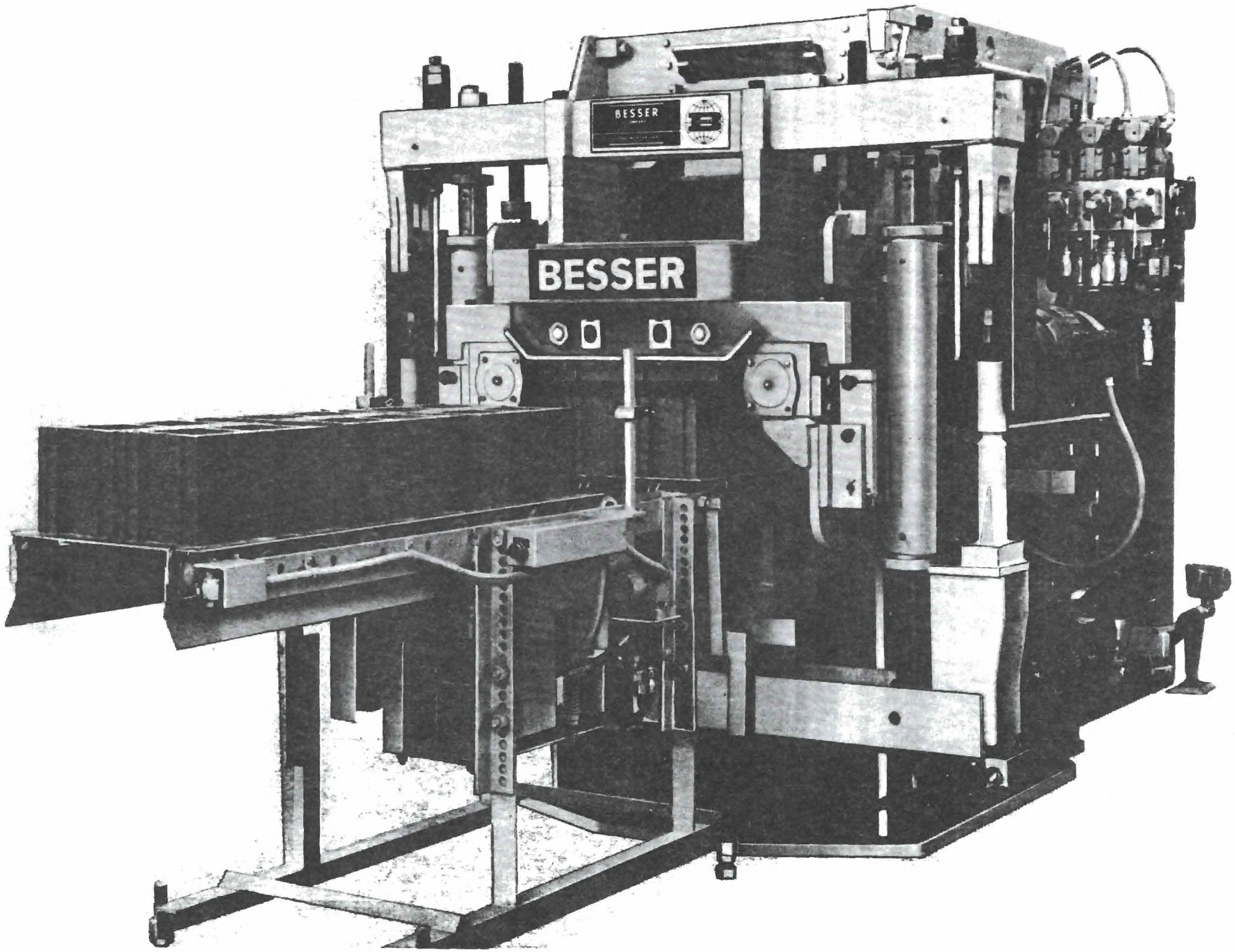


Figure 3-5. Automatic Blockmaking Machine
Equivalent to Machine 6 in Table 3-1

Picture Courtesy of Columbia Machine, Inc.

Figure 3-6. Automatic Blockmaking Machine
Equivalent to Machine 6 in Table 3-1

Picture Courtesy of Besser, Co.


BESSER
BESSER

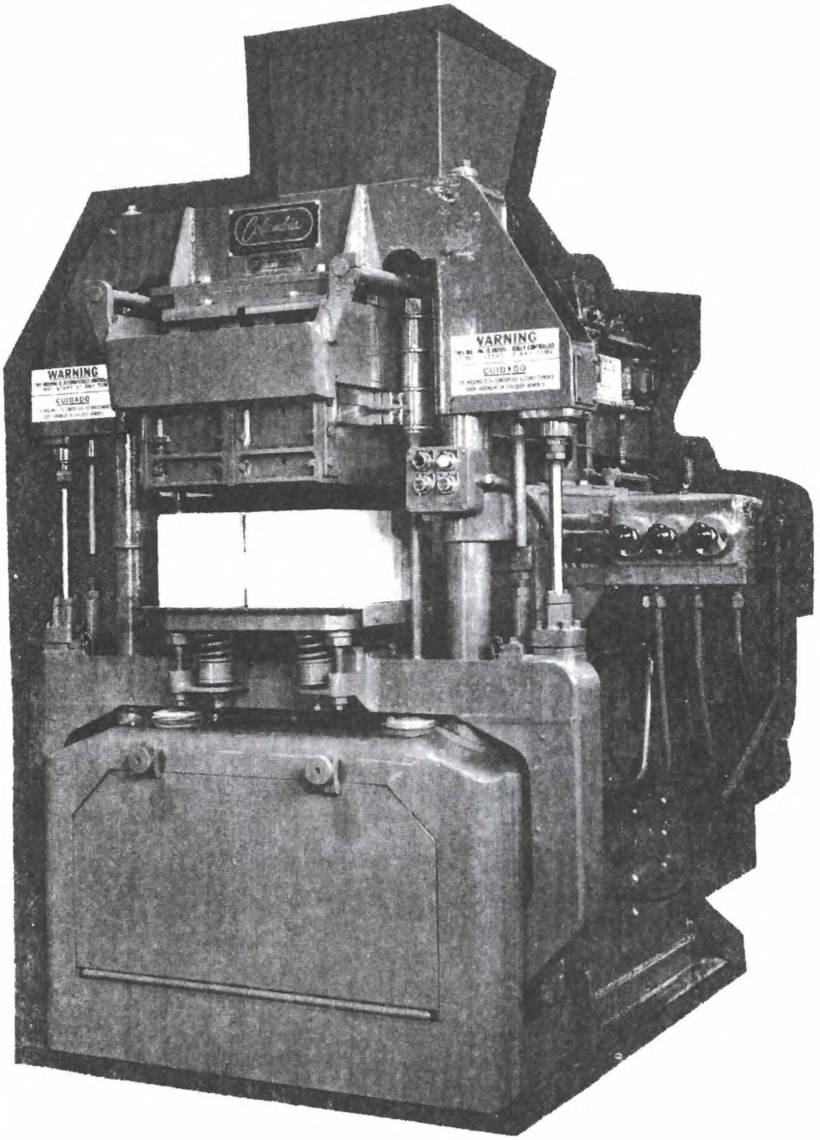


Figure 3-7. Automatic Blockmaking Machine
Equivalent to Machine 7 in Table 3-1

Picture Courtesy of Columbia Machine, Inc.

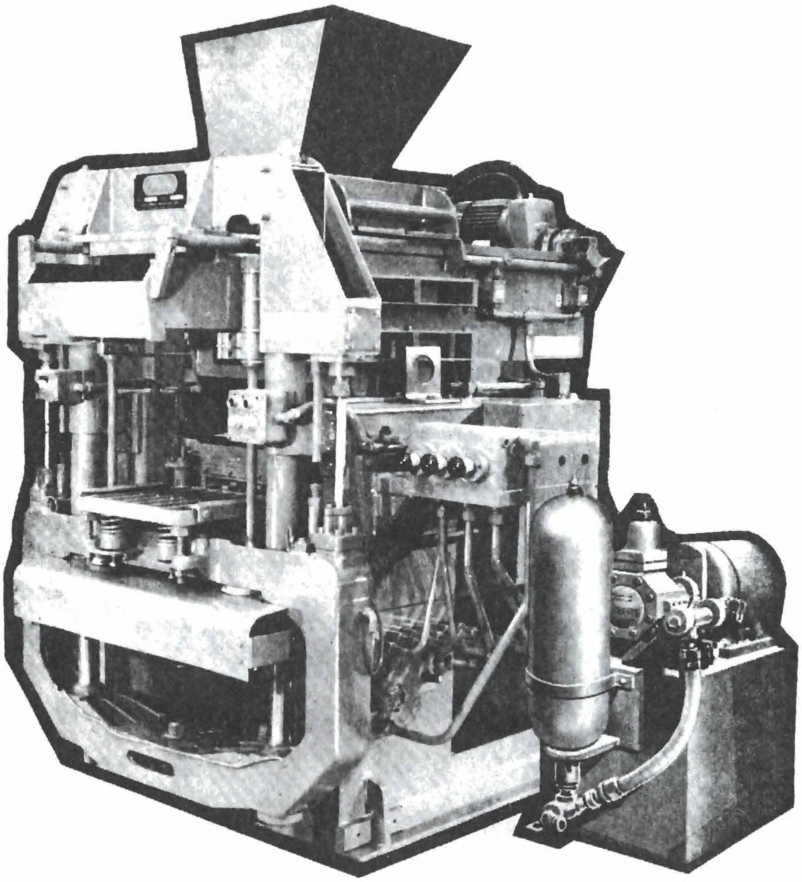


Figure 3-8. Automatic Machine
Equivalent to Machine 8 in Table 3-1

Picture Courtesy of Columbia Machine, Inc.

Table 3-1. Automatic Forming Machines

TYPE OF MACHINE	CAPACITY*			POWER	COST**
	Block/8-Hr. Shift	Cycles/Minute	Blocks/Cycle	H.P.	U.S. Dollars
1	23,000	3.50	12	120	175,000
2	16,000	6.66	5	75	150,000
3	14,000	7.30	4	60	140,000
	14,000	9.75	3	55	140,000
4	12,500	8.70	3	55	115,000
5	9,000	6.00	3	45	75,000
6	7,500	7.80	2	30	60,000
7	4,500	3.00	2	23	30,000
8	2,000	3.20	1	14	20,000

*Figure for full capacity of the machine. Details on factors affecting capacity are discussed below.

**Including one mold for standard blocks, each additional mold costs between 2,500 and 12,000 U.S. Dollars depending on the size of the machine.

machines in the block production that were bought 25 years ago and still run well.

Semi-Automatic Blockforming Machine

There are presently few manufacturers producing semi-automatic blockforming machines.

The description which follows is based on a machine made by a manufacturer who has specialized in block machinery characterized by low price, semi-automatic operation, and low rate of production output.

The machine does not work continuously or automatically, and the operator has to take some direct actions in the operation by depressing buttons and handling levers. The block is formed by vibration, provided by two motors, and compression applied by means of a lever and a hydraulic mechanism. To make the block, enough concrete for several cycles is deposited in a hopper on top of the machine and each cycle a pallet is placed manually in the mold. The machine is activated and the mold is filled automatically by means of a mechanism that hydraulically moves it back under the hopper to receive the concrete, and moves it forward to its original position. Then the concrete is vibrated and compressed to form the blocks, which in turn are automatically stripped from the mold. The blocks on the pallet can now be offbeared, and a new pallet placed in the machine to start a cycle again.

The capacity of this type of blockforming machine is about 2,000 standard blocks per eight-hour shift, producing three standard blocks at a time.

Table 3-2 summarizes the capacity, initial cost, and horsepower estimations of the semi-automatic blockforming machine, and Figure 3-9 shows the most popular of these machines.

Table 3-2. Semi-Automatic Forming Machines

TYPE OF MACHINE	CAPACITY			POWER	COST*
	Block/8-Hr. Shift	Cycles/Minute	Blocks/Cycle	H.P.	U.S. Dollars
9	2,000	1.4	3	12	17,000

*Figures for cost include a mold for standard block; each additional mold costs about 2,800 U.S. Dollars, and are available for 4"x8"x16", 12"x8"x16", and 4"x12"x12" blocks, producing 6,4,2,2, and 2 blocks per pallet respectively.

To operate a semi-automatic forming machine an operator and a worker are needed.

Figure 3-9. Semi-Automatic Machine

1. Motors Control
2. Lever
3. Vibrating Motor
4. Mold Compartment
5. Hopper

This machine can be automated by adding to it a pallet magazine and ejector for continuous pallet feeding as well as a programmer with solenoid bank for automatic machine cycling.

Picture Courtesy of Fleming Manufacturing Co.

The machine is as rugged and well built as the automatic one, and its service can be expected to be even longer. The maintenance is similar. However, since it works at lower speeds, its parts wear out much less. Because of the simplicity of its design the parts are not expensive, and maintenance turns out to be cheaper.

One more important thing has to be said to complete the description. By adding some special equipment, the machine can function automatically. The cost of this optional equipment is about 50% of the original cost, and the capacity is raised to 2.5 cycles per minute. Only one operator is needed to attend the operation.

Manually Operated, Powered Blockforming Machines

Manual, Powered Blockforming Machine

This is a one-block-at-a-time machine which is shown in Figure 3-10. It makes the block by vibration and compression of the concrete. The machine has an electric motor (three horsepower) to produce vibration and two levers, one to press the concrete and turn over the mold once the pallet is set in its place and other to strip the block from the mold. The operator does not have to handle either the mold or the cores, resulting in a relatively fast manual operation. To make the block the vibrator is started and the mold filled with concrete which is shoveled or deposited from a hopper. Then the pallet is placed on top of the mold which is turned over. While turning it over certain mechanical pressure applied completes the compaction. The block is now stripped from the mold ready to be offbeared. The block quality achieved is very good.

The machine can be operated by one man who changes it with concrete,

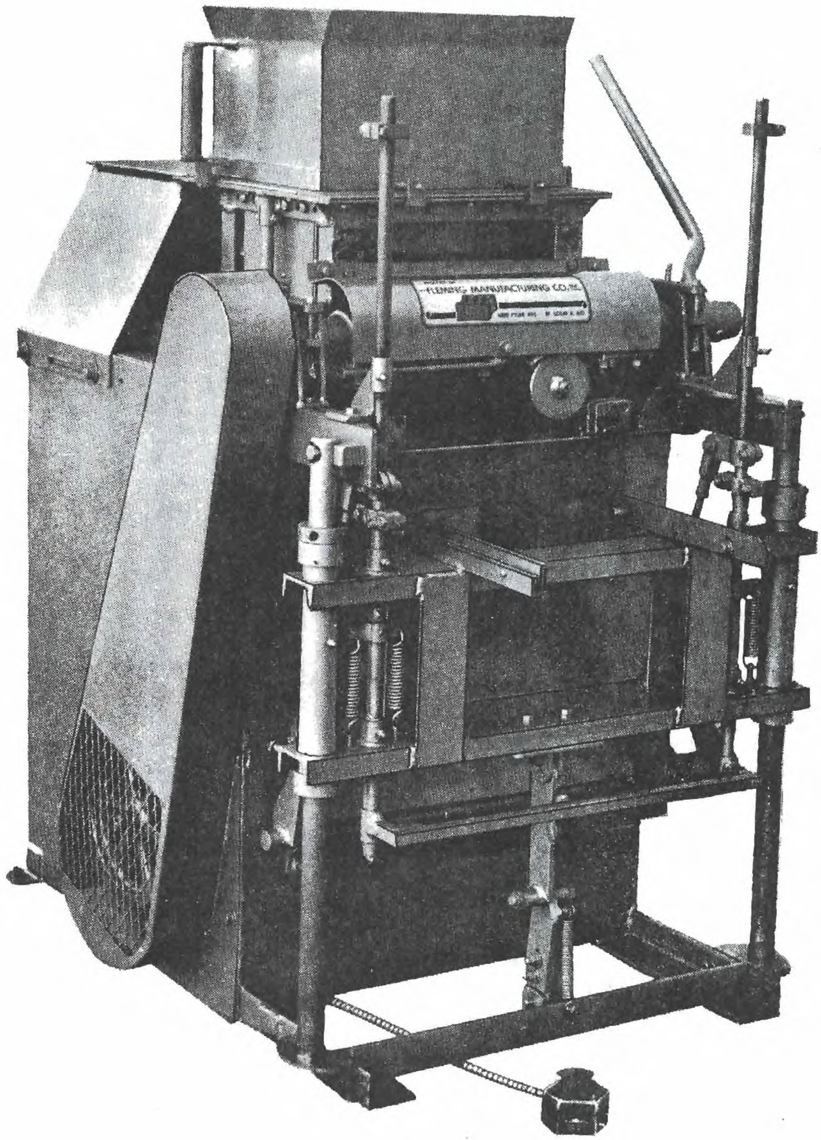


Figure 3-10. Powered-Manual Machine
Equivalent to Machine 10 in Table 3-3

Picture Courtesy of Fleming Manufacturing Co.

forms the block, and if required retires the block from the machine. Up to 800 standard units per eight-hour shift can be produced.

The initial cost is about \$4,000 U.S. Dollars. Maintenance expenses are very low since the design is simple and the machine is solid and sturdy.

Vibrating Table Blockforming Machine

In this kind of machine one or two blocks can be made at a time. The compaction of the concrete is made by vibration applied to a plate where a mold is fixed, or directly to the mold or core. The vibration is produced by means of electric vibrators or a cam mechanism driven by a motor. To make a block, the mold with a pallet in, is placed on the plate, filled with concrete, and vibrated. Then the block on its pallet is stripped from the mold and carried away. Good compaction and consequently good block can be obtained. Figure 3-11 shows a photograph of a vibration table.

Depending on the size of the machine, from 200 to 400 standard blocks can be produced per eight-hour shift.

The cost of the vibrating table, including the mold box, is about \$600 and \$1,000 U.S. Dollars for small and large tables respectively.

The vibrator motor is one to two horsepower. The machine is operated by one worker, but a material handling man is required to charge the mold with concrete, and usually one or two men to offbear the blocks.

The maintenance turns out to be very little since only the vibrators need regular attention and it is very cheap for electric motors are practically trouble-free.

In order to continue with an organized description of blockforming machines, Table 3-3 summarizes the types of manual-powered blockforming machines.

Table 3-3. Manual-Powered Forming Machines

TYPE OF MACHINE	CAPACITY			POWER	COST
	Block/8-Hr. Shift	Cycles/ Minute	Blocks/ Cycle	H.P.	U.S. Dollars
10*	800	1.66	1	3	4,000
11**	400	0.83	2	2	1,000
12**	200	0.41	1	1	600

*Manual, powered machine
**Vibrating table

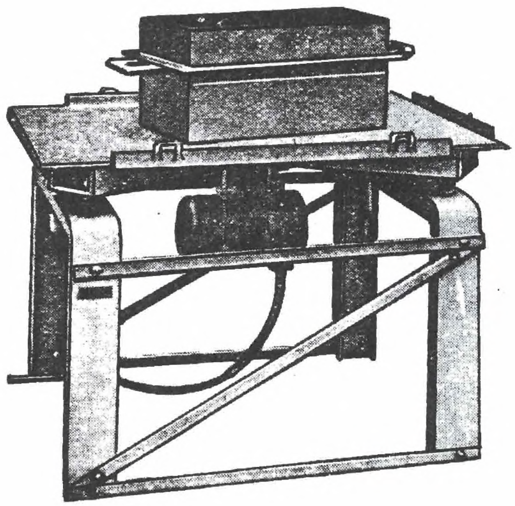


Figure 3-11. Vibrating Table Machine

Picture Courtesy of R.L. Spillman

Manual Blockforming Machines

Hand Operated Tamping Machine

These machines consist essentially of a metal box forming the mold supported on a waist-high stand. The core of the block (if needed) is inserted, usually horizontally, to permit the action of the tamper. Vertical cores can be used if a special tamper is designed. A hand-operated tamping plate is hinged to the frame and in some machines it is counterbalanced by a spring or weight. The bottom of the mold can be made to move upwards by means of a hand or foot-operated lever.

To make a block a pallet is dropped into the mold. Concrete is shovelled in and compacted by five or six blows of the tamper. The cores are then withdrawn, and the block on the pallet is raised clear off the mold by means of the lever, and carried away for hardening. Figure 3-12 shows a typical machine of this type.

Hand operated machines can produce up to 500 standard block per eight-hour shift. Their cost vary from $500 to $800 U.S. Dollars. The machine is operated by one worker and a material handling man. A carrier or two are needed. They are sturdy machines and maintenance is practically neglectable. Plywood pallets are usually used, but steel pallets last longer.

Mold and Tamper

This is the simplest machine of all. It consists of a wooden or metal box whose depth is equal to the combined thickness of the block and pallet. One or more of the sides is hinged to the bottom plate and held in the closed position by hooks, screws, or a strap. To make hollow blocks, cores are inserted in the mold box. Cores can be placed either

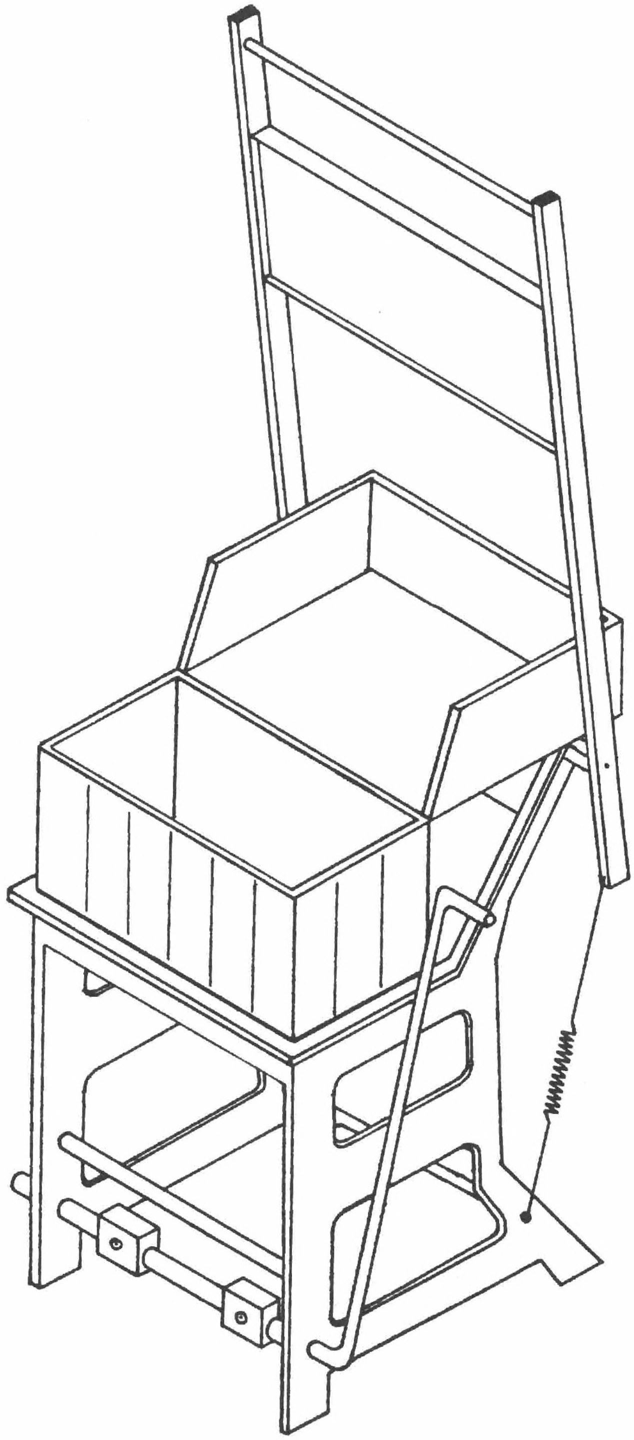


Figure 3-12. Hand Operated Tamping Machine

horizontally or vertically. Figure 3-13 and Figure 3-14 show some typical molds.

To make a block, a wooden pallet is placed in the box, and concrete is shoveled in and compacted by blows from a punner, a metal plate on a stick, or a shovel. The cores are then carefully withdrawn, and the sides of the box let down. The block on the pallet can be now carried to harden.

To maximize the time that the molds are used, two workers per mold are required, and a third worker prepares and serves the concrete. While one of the men does the forming, the other one receives the freshly formed block and carries it to curing. Sometimes the workers work alternately and while one is carrying his own block, the other is forming a new block. Four workers with two molds, and a material handling man can produce close to 250 standard blocks in an eight-hour shift if they work steadily.

This equipment is cheap and robust, and requires practically no maintenance. One mold costs about $100 U.S. Dollars.

Table 3-4 shows a summary of manual machines.

Table 3-4. Manual Forming Machines

TYPE OF MACHINE	CAPACITY			POWER	COST
	Block/8-Hr. Shift	Cycles/ Minute	Blocks/ Cycle	H.P.	U.S. Dollars
13*	500	1.04	1	-	650
14**	120	4.00	1	-	25 to 100

*Tamping machine
**Molds

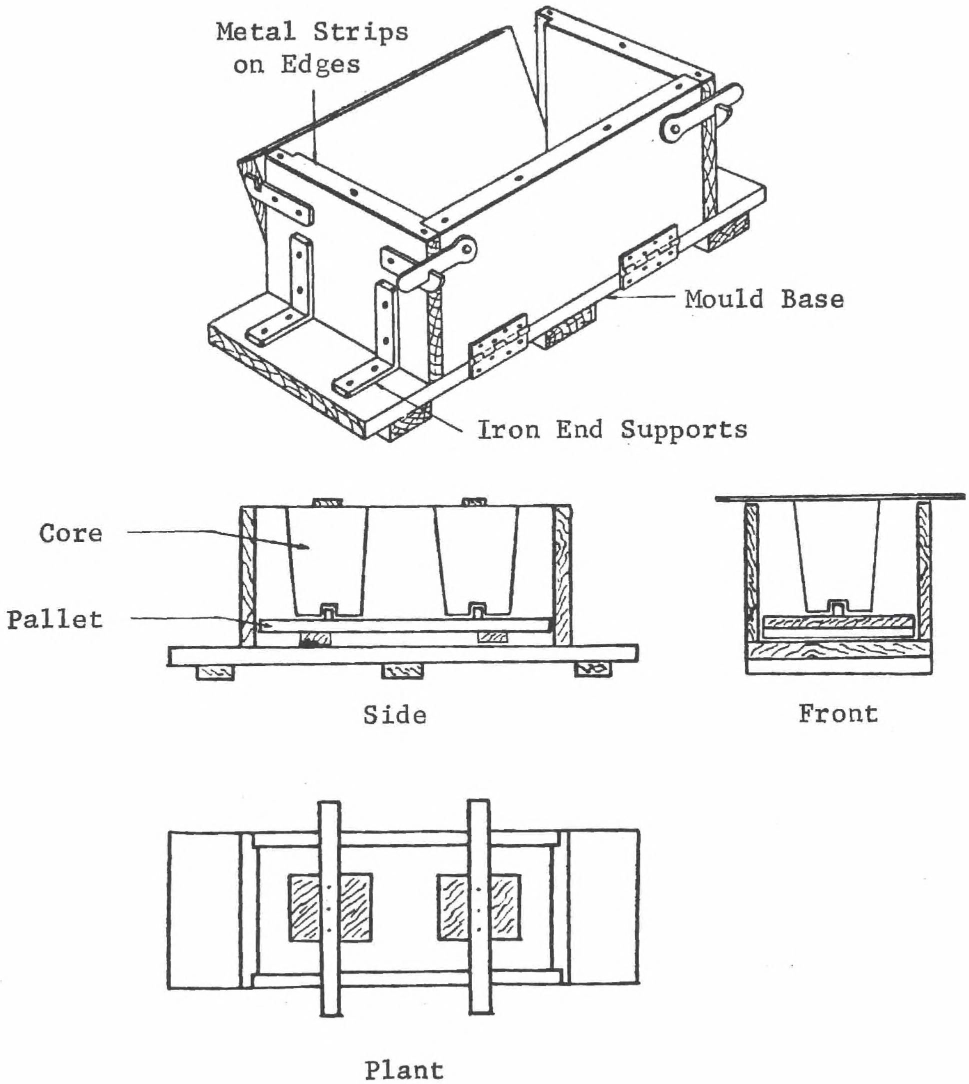
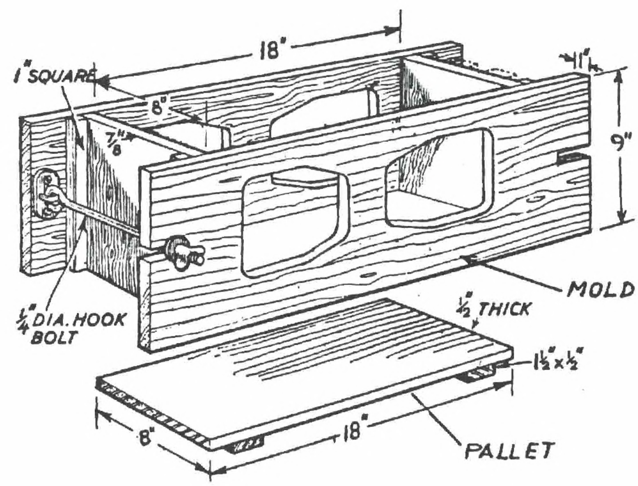


Figure 3-13. Wooden Hinged Mold Box

The cores are placed vertically as shown in front and side views. They may be held in position by a dowel, fixed to the pallet and fitting into a hole in the bottom of the core. Cores can be held in position by dowels, fixed to the edges of the mold's walls and fitting into a hole in the handles of the cores.



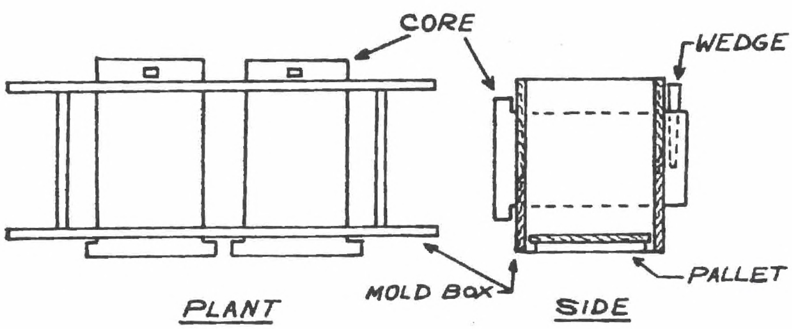


Figure 3-14. Mold Box Fixed with Ring-Bolts

Cores are inserted in the cavities on mold and fixed with a wedge as shown in the figure.

Manual machines are not currently produced by specialized equipment manufacturers since most of the concrete block producers have moved toward automatic machinery. However, their construction is not difficult and a machine can be made under special order by a contractor or perhaps an experienced carpenter.

Stage III. Block Handling

Part 1. Equipment Available

This section deals with the description of equipment available for the block handling activity of the block production process.

As shown in the flow process chart (Figure 2-2), block handling is composed of seven handling operations and one in-process storage as follows:

Stage III, Block Handling:

8. Offbear block from machine, and load in-process storage;
9. In-process storage;
10. Convey to curing;
12. Retire from curing;
13. Unload in-process storage device;
14. Depalletizing and feeding pallets into machine;
15. Cubing; and
16. Yarding cubed blocks.

Based on this sequence of operations, information collected from equipment manufacturers and concrete block producers was used to classify types of equipment into levels of technology as follows: automatic, semi-automatic, mechanized, semi-mechanized, and manual. These classes represent the degrees of automation and sophistication involved in the block handling.

The results of this classification are indicated on Table 3-5 which serves as a guide for the description of the equipment of each

Table 3-5. Table of Equipment Used for The Block Handling Activity of the Process

TECH. LEVEL	SETS OF EQUIP.	OPERATIONS						
		8	10	12	13	14	15	16
		Offbear Block and Load In-Process Storage	Carry to Curing Area	Retire from Curing Area	Unload In-Process Storage	Depalletize and Feed Pallets Back into Machine	Cube	Yard Cubed Blocks
A	A_1	Automatic	Automatic	Automatic	Automatic	Automatic	Automatic	Lift Truck
	A_2	Automatic	Automatic	Automatic	Automatic	Automatic	Semi-Auto.	Lift Truck
B	B_1	Automatic	Lift Truck	Lift Truck	Automatic	Automatic	Automatic	Lift Truck
	B_2	Automatic	Lift Truck	Lift Truck	Automatic	Automatic	Semi-Auto.	Lift Truck
	B_3	Automatic	Lift Truck	Lift Truck	Automatic	Automatic	Manual	Lift Truck

Table 3-5. Continued

TECH. LEVEL	SETS OF EQUIP.	OPERATIONS 8 Offbear Block and Load In-Process Storage	10 Carry to Curing Area	12 Retire from Curing Area	13 Unload In-Process Storage	14 Depalletize and Feed Pallets Back into Machine	15 Cube	16 Yard Cubed Blocks
C	C_1	Mechanized	Lift Truck	Lift Truck	Mechanized	Semi-Auto.	Semi-Auto.	Lift Truck
	C_2	Mechanized	Lift Truck	Lift Truck	Mechanized	Semi-Auto.	Manual	Lift Truck
	C_3	Mechanized	Lift Truck	Lift Truck	Mechanized	Semi-Auto.	Manual	Hand Truck
	C_4	Mechanized	Lift Truck	Lift Truck	Manual	Mechanized	Semi-Auto.	Lift Truck
	C_5	Mechanized	Lift Truck	Lift Truck	Manual	Mechanized	Manual	Lift Truck
	C_6	Mechanized	Lift Truck	Lift Truck	Manual	Mechanized	Manual	Hand Truck
	C_7	Mechanized	Lift Truck	Lift Truck	Manual	Manual	Manual	Lift Truck
	C_8	Mechanized	Lift Truck	Lift Truck	Manual	Manual	Manual	Hand Truck
D	D_1	Manual	Jack Lift	Jack Lift	Manual	Manual	Manual	Hand Truck
	D_2	Manual	Conveyor*	----------	----------	Manual	Manual	Lift Truck
	D_3	Manual	Conveyor*	----------	----------	Manual	Manual	Hand Truck
E	E_1	----------	Manual	----------	----------	------------	----------	----------

*Cable Conveyor

level of technology. Highly automated equipment or level of technology A is treated first moving backwards to fully manual equipment or level of technology E.

The first column of the table represents the levels of technology of the block handling equipment available, and the second column stands for particular setups or variants of each level of technology.

The sets of equipment that are classified under the same level of technology have the same basic characteristics and the same capability to perform the block handling activity. However, those variants make them deserve to be depicted separately, offering a better idea of each level of technology.

Standing for each operation and labeled with their respective numbers and headings, the next seven columns represent the operations of the block handling activity. Under each column the terms typify the equipment available for that operation, i.e., for operation eight, automatic, mechanized, and manual types of equipment are available.

The lines of the table depict the optional setups within a level of technology, i.e., the first line illustrates a fully automatic set of block handling equipment (A_1), while the sixth line illustrates a mechanized set (C_1) by which operations eight and thirteen are performed mechanically, operations ten, twelve, and sixteen by means of a powered fork-lift truck, and operations fourteen and fifteen semi-automatically.

After the five levels of technology and their optional sets are described (including their main characteristics on performance, capabilities, type of labor required, energy consumed, and some typical layouts) the reader will have a good idea of the equipment available to handle the green and cured concrete block throughout the process.

The description of each level is made in two steps. First, operations eight, ten, twelve, and thirteen are explained, then operations fourteen, fifteen, and sixteen conclude the explanation.

The reason for this is that operations eight and thirteen, as well as ten and twelve are closely related as mentioned in Chapter II.

Block Handling Equipment Level of Technology A: Automatic

This is the most highly automated type of equipment. Machinery classified under this level can carry out the whole block handling activity automatically.

There is no need to control and activate each operation. The activity is performed continuously from the time the blocks are formed and offbeared to the time they are conducted to the yard. This allows the machine to work continuously and at full capacity.

The equipment has the capability to handle as many blocks as an automatic forming machine can produce.

There are many sizes available with capacities to handle from 23,000 to 8,000 standard blocks per eight-hour shift. The difference between equipment of different sizes is based only on the size of the pallets that can be handled and the rate of handling capacity. However, the same characteristics in design and operation are kept. The bigger the pallets, the more power it should have; and the higher the rate of production, the faster it should operate. A specially designed set of equipment is available for any given capacity, and it is adjustable to operate at any desired pace. Because of the internal complexity of the equipment, well trained, experienced people are needed on the operation.

Details on number and functions of each worker are given later in the Chapter.

Operations 8, 10, 12, and 13. There are two types of design for fully automatic blockhandling equipment. The main difference between them is the in-process storage device which can either be mobile (standard rack), or fixed in the kiln or curing area.

In the first case, the equipment consists of an automatic loader-unloader and a transfer car. These two units work together. The loader-unloader receives the pallets of green blocks from the automatic forming machine and moves them to a rack (Operation 8); when a rack is full, the transfer car transfers it to the kilns (Operation 10), and brings a rack of cured block (Operation 12) back to the loader-unloader which unloads this rack (Operation 13) and moves it forward to be reloaded with green blocks to start the cycle again. Figures 3-15 and 3-16 show this type of equipment and schematically explain its operation.

In the case of having the racks fixed in the kiln the order of the process is slightly changed. The pallets of green block are transported on a conveyor (Operation 10*) directly from the machine to the door of the kiln. Then they are moved into the kiln and set on the racks (Operation 8). After curing, the pallets are pushed off the rack (Operation 13), and retired from the curing area on a conveyor (Operation 12). Figures 3-17 and 3-18 depict two typical layouts of this type of equipment.

*In this case Operation 10 is labeled "offbearing and carrying green block to curing area," and Operation 8 is denominated "loading in-process storage."

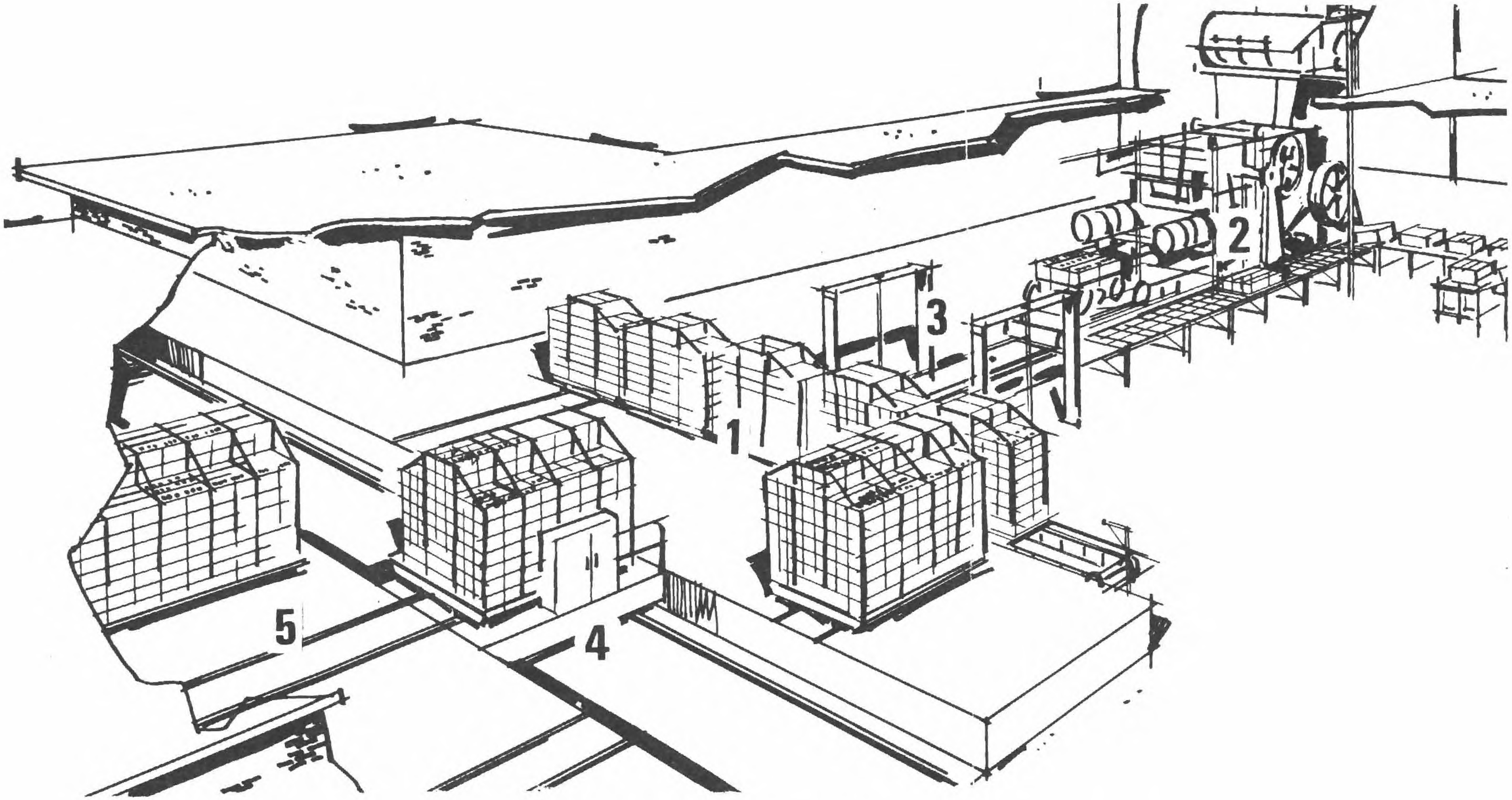


Figure 3-15. Rack Loader-Unloader Transfer Car System

1. Mobile Racks 2. Blockmaking Machine 3. Automatic Rack Loader-Unloader 4. Transfer Car
5. Kilns

Picture Courtesy of Besser Co.

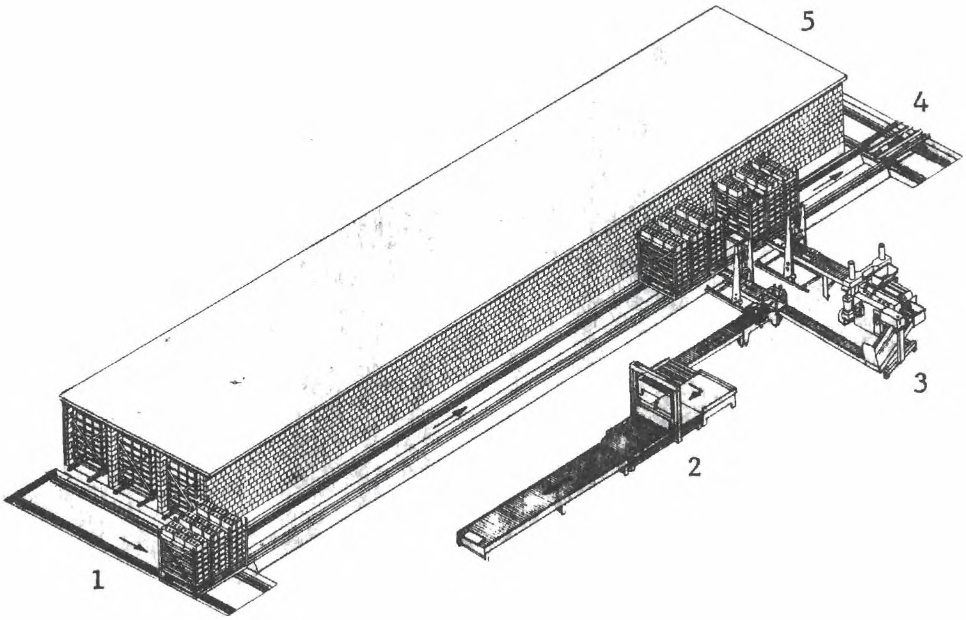


Figure 3-16. Rack Loader-Unloader Transfer Car System

1. Unloading Transfer Car receives rack of cured blocks from the kiln, then automatically carries it to tracks leading to the unloading section of an Automatic Rack Loader-Unloader.

2. Cubing Machine

3. Block Machine with newly made blocks being placed in racks by an Automatic Rack Loader-Unloader. Filled racks are automatically moved to the Transfer Car for placement in the kilns.

4. The loading Transfer Car moves on rails running parallel to the kiln doors. It includes a self-contained hydraulic pusher to move loaded racks into the kilns.

5. Automatic insertion of green blocks into the kiln is accomplished by the loading Transfer Car. An unloading Transfer Car at the opposite end of the kiln is receiving cured blocks.

Picture Courtesy of Columbia Machine Inc.

Figure 3-17. Block Handling Equipment with Racks Fixed in the Kiln

1. Pallets of block ride on a conveyor from the block machine to the front of the kiln.

2. An automatic pusher slides the pallets into slots in stationary shelves in the kiln.

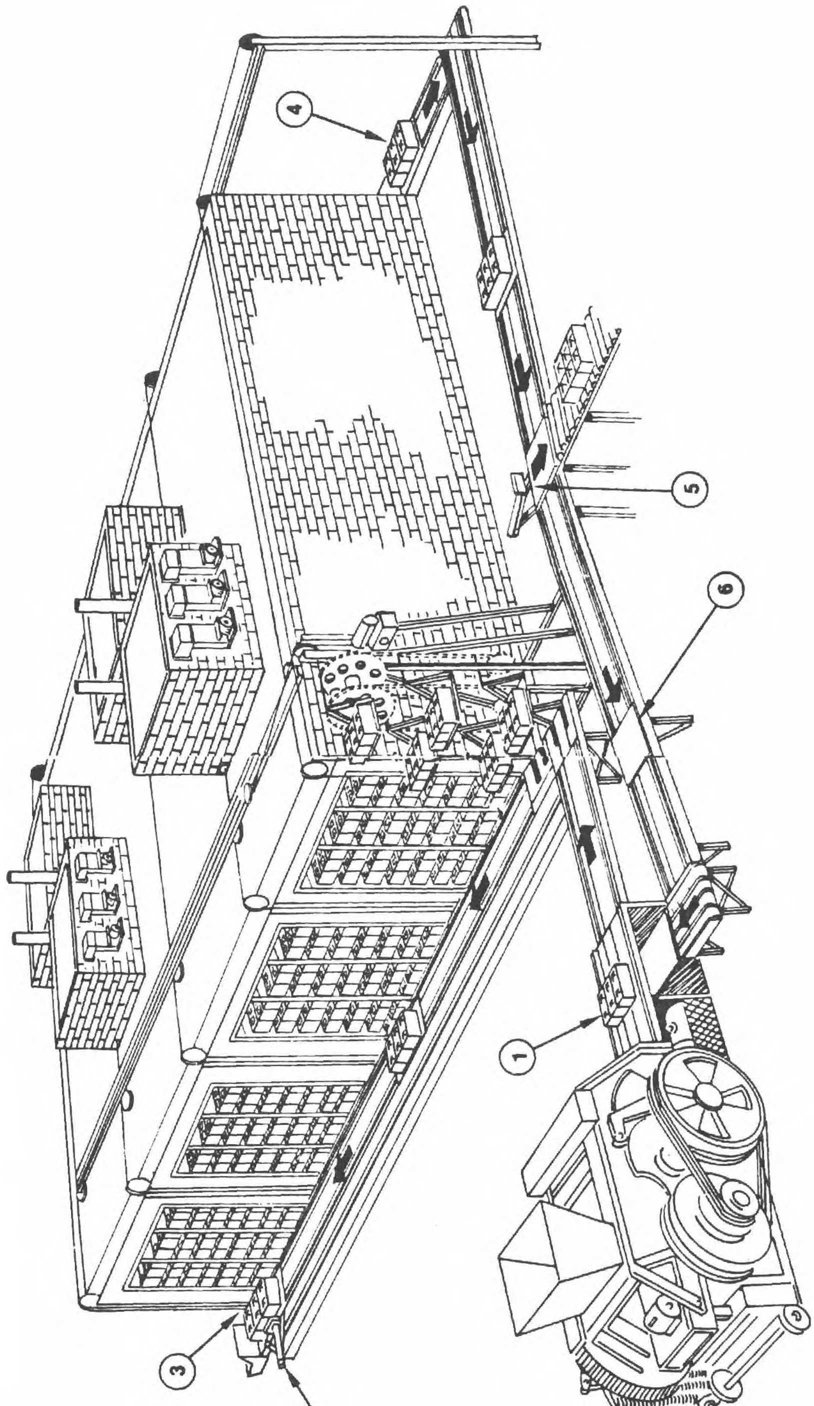
3. When one shelf in the kiln is filled with uncured block, the conveyor automatically moves up or down to the next shelf so the pusher can fill it.

4. As each pallet of uncured block is pushed in the front of the kiln, a pallet of cured block comes out the back and is gently placed on the conveyor.

5. Cured blocks are pushed off the pallet by a depalleter and go to the cuber.

6. The empty pallets are conveyed back to the block machine.

Picture Courtesy of Builders Equipment Co.


1
2
3
4
5
6

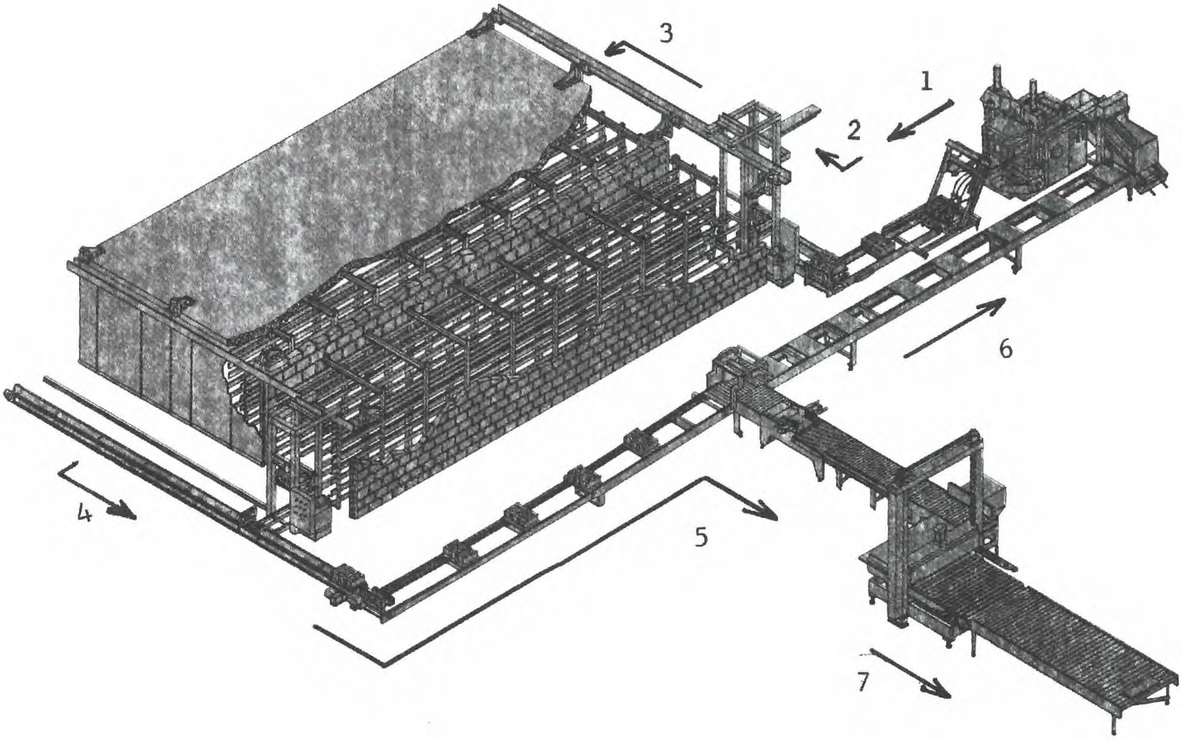


Figure 3-18. Block Handling Equipment with Racks Fixed in the Kilns

1. From the block machine, green blocks move onto a lowering elevator and pass through an inspection station.

2. Pallets are carried at floor level to the kiln-loading station.

3. The kiln loader moves horizontally on tracks and stops at the proper loading bay. With positive locking device engaged, the three pallets are gently pushed into the rack.

4. As three pallets are pushed into the rack, three pallets of cured blocks are simultaneously pushed from the kiln into the awaiting unloader mechanism.

5. Cured blocks move to the push-off station where the pallets are forwarded to the pallet return conveyor and the blocks advance to the clamp turnover.

6. Pallets travel along the pallet return conveyor to be brushed clean and deposited in the block machine pallet magazine.

7. At the cuber, blocks are formed into interlocking cubes ready for the yard.

Picture Courtesy of Columbia Machine Inc.

Operation 14. Automation for depalletizing and feeding pallets into machine (Operation 14) is an intrinsic characteristic for both mobile and fixed rack design. In either case when the racks are unloaded the pallets of cured block travel on a conveyor to a depalletizer or push-off device which separates the blocks from the pallets. A pallet magazine receives the pallets and automatically feeds them to the machine.

Operation 15. While the pallets are conveyed back to the machine, the cured blocks are transported to the cubing area. Automatic and semi-automatic cubing equipment is available at this level of technology. These two options bring about two sets of equipment (A_1) and (A_2).

Automatic cubing turns the block over (if needed), forms the patterns, and stacks the tiers to form the cube. The work is done continuously and does not require a full-time operator. The operator has to program and control the operation being able to attend some other task at the same time.

Figure 3-19 shows an automatic cubing system.

The difference between automatic and semi-automatic cubing equipment is that the latter requires a man devoted full time to operate it. He turns the block over (if needed), forms the patterns, and activates the cuber which automatically stacks the tiers to form the cube.

Figure 3-20 shows a semi-automatic cubing system in progress.

It is important to mention at this point that many block manufacturers whose plants are equipped with automatic block handling equipment (Level A) prefer the semi-automatic over the automatic cuber. The reason is that at some place in the process a quality control inspection must be done. The operator at the semi-automatic cubing area can be responsible

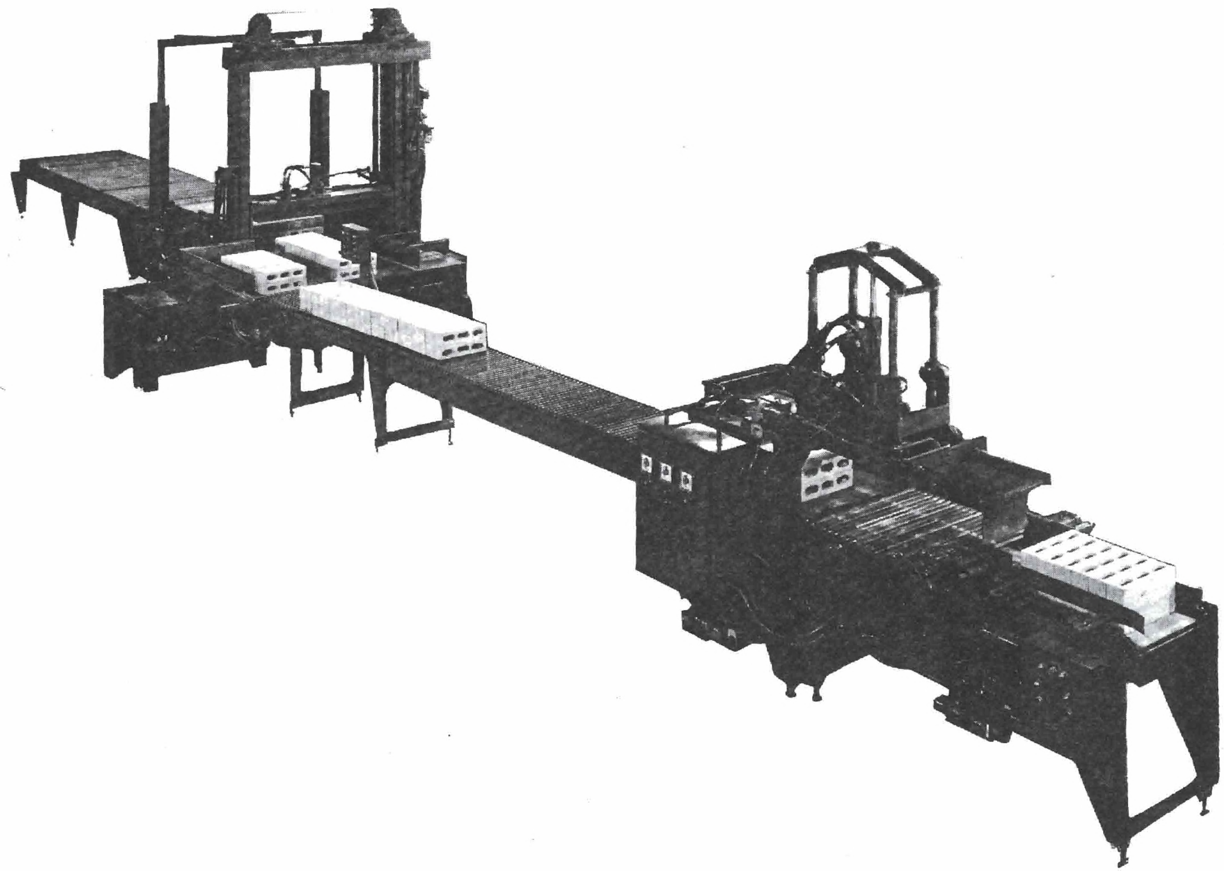
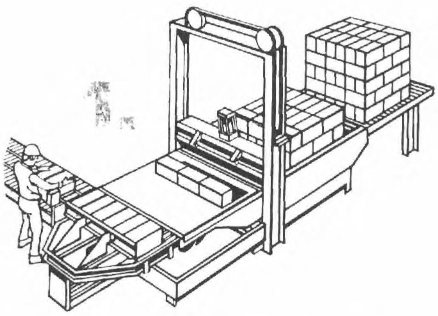
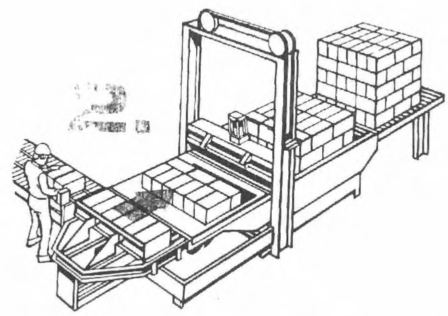


Figure 3-19. Automatic Cubing System

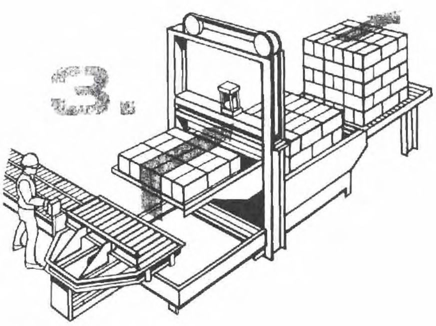
Picture Courtesy of Columbia Machine Inc.



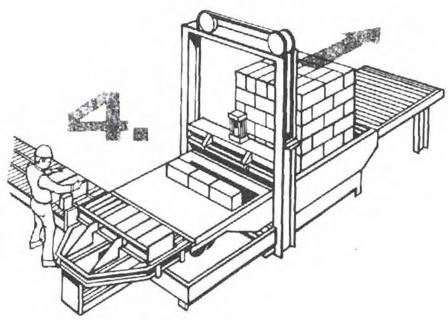
As cured blocks move by on conveyor, operator culls and arranges pattern. First course is turn unless blocks are palletized.



Operator pushes button as row is completed and blocks are automatically moved onto the table. Pattern can be changed without interrupting cycle.



When course is complete, push button control moves the table up and over partial cube. Next, the stop gate drops and the new course becomes part of the cube as the table returns to original position.



Powered conveyor moves completed cube away for pick-up while operator begins next course.

Figure 3-20. Semi-Automatic Cubing System

Picture Courtesy of Praschak Machine Co.

for such a task without any extra effort or time consumption. It is true that some equipment is available for automatically inspecting blocks, but it does not perform as well as a unit-by-unit, visual inspection. A second reason, but not less important, is that automatic cubing systems are more expensive than the semi-automatic type. Also despite the fact that the operator does not have to devote full time to an automatic cuber, he has to spend a good deal of his time at the machine for one reason or another. Consequently, block manufacturers select semi-automatic cubing systems most of the time.

Operation 16. After the block is cubed the last operation of the block handling activity, and of the whole process is to carry the cubed blocks to the yard. This is the only operation that has not been automated. The cubes are picked up by a fork-lift truck and carried to the yard.

Conventional fork-lift trucks are used. They are usually 8,000; 6,000; or 4,000 pounds fork-lift trucks, depending on the size of cubes to be moved.

Block Handling Equipment Level of Technology B: Semi-Automatic

Except for Operations 10 and 12, the rest of the activity is worked automatically and with the same type of equipment used in Level A.

Instead of a transfer car, a fork-lift truck is used to carry the loaded racks to the curing area and bring them back to the rack loader-unloader. The racks are always mobile.

Since Operations 8 and 13 are still automatic (automatic rack loader-unloader) at this level, the forming machine can run continuously and very close to full capacity.

If the fork-lift truck operator is experienced enough to keep up with the pace at which the racks are loaded and unloaded, the production can be as high as that obtained with the same machine and block handling equipment of Level A. This can be regularly done for medium size machines of the order of 9,000 standard blocks per eight-hour shift; however, it would be hard to keep up with the rate of production of bigger machines.

Thus, it is reasonable to assume that large machines output (Machines 2, 3, and 4 from Table 3-1) are reduced from 8% to 10%, and that smaller machines output (Machine 5 and 6 from Table 3-1) are not affected at all.

Equipment of this type requires skillfull labor as well.

Operations 8, 10, 12, and 13. After a rack is loaded (Operation 8) the fork-lift truck picks it up, conveys it to the curing area, and places it into the kiln (Operation 10). Then the truck picks up a rack of cured block and takes it to the automatic rack loader-unloader, setting it in the rack conveyor (Operation 12). In its turn, the loader-unloader unloads the rack (Operation 13) and moves it to the loading side to be reloaded. Figures 3-21 and 3-22 present two types of rack loader-unloader for fork-lift truck.

Operation 14. As in Level A, automation for depalletizing and feeding pallets into the machine is an intrinsic feature of Level's B block handling equipment.

Operation 15. Automatic and semi-automatic cubers, exactly like the ones discussed for Level A are used at this level of technology also. However, a third variant of the cubing equipment is included for Level B:

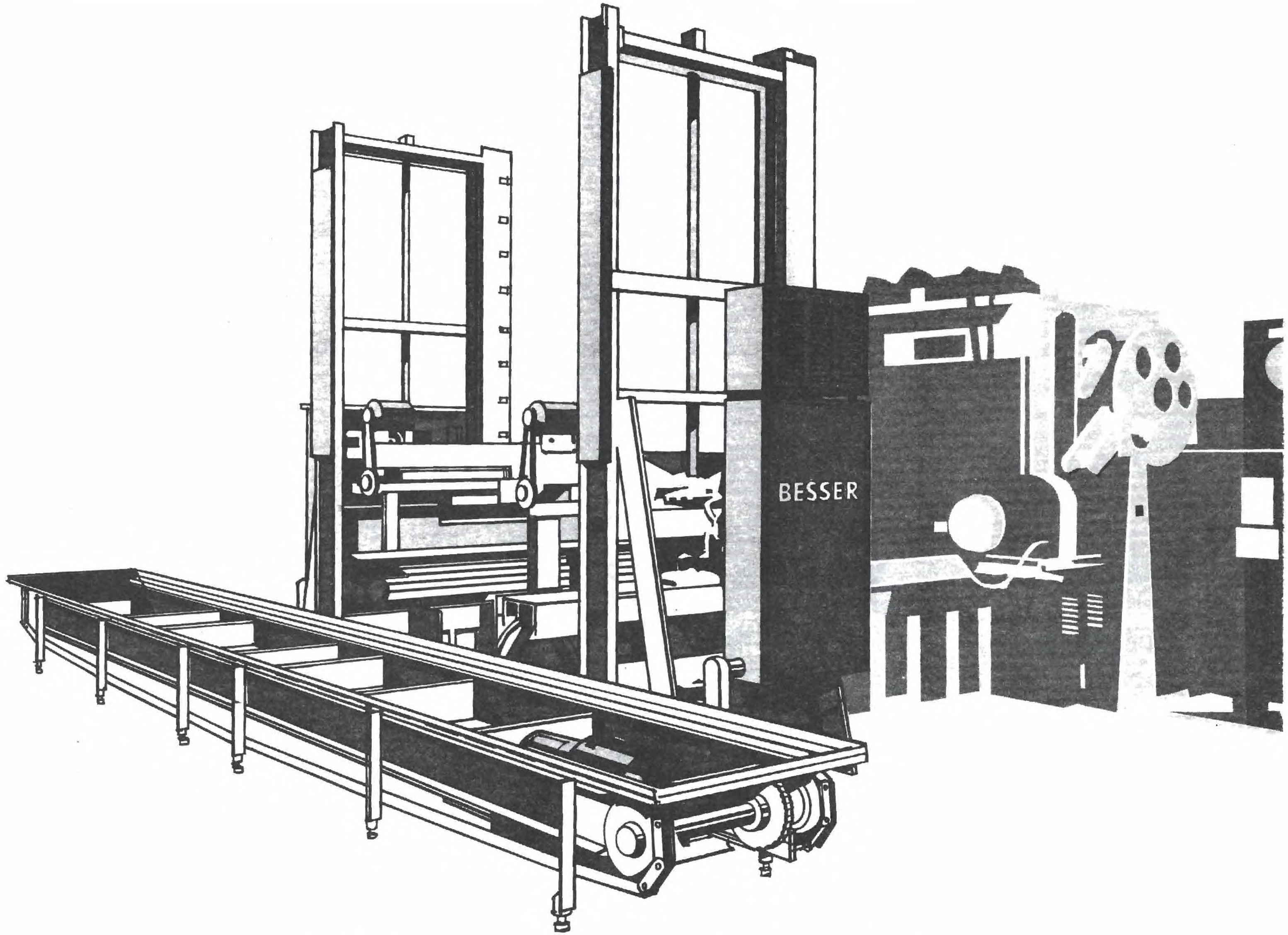


Figure 3-21. Rack Loader-Unloader for Fork-Lift Truck
Picture Courtesy of Besser Co.

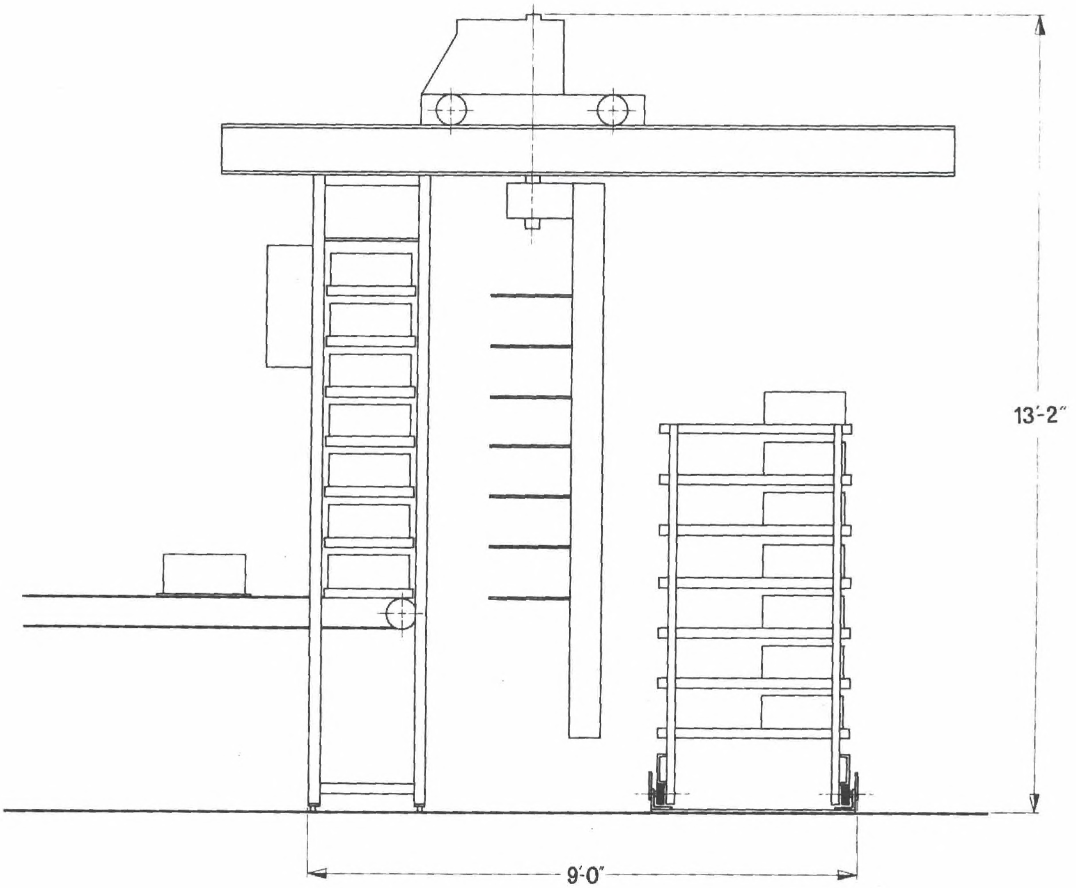


Figure 3-22. Lateral View of a Spade Type Rack Loader-Unloader for Fork-Lift Truck

This figure shows only one side of the Loader-Unloader. As the pallets of block come from the machine the accumulator (A) stacks them. When it is full the loader spades (B) move toward the left, picks up the pallets and moves backwards rotating 180°. Then the pallets of block are placed in the rack (C). The fork-lift truck retires now the rack to the kiln. The unloader spades (not shown) pick up the cured block from a rack and transfer them to another accumulator which moves the pallets of block onto a conveyor leading to the cubing area.

Picture Courtesy of Paco Corporation

manual cubing equipment.

Cubing by hand takes much more labor than cubing with automatic or semi-automatic equipment. Nevertheless, except for a short conveyor, no equipment is needed and it is worthwhile to analyze the alternative.

Making the cubing manually does not interrupt the continuity of the operation, and the rest of the equipment can still work at the same rate as if cubing were made automatically or semi-automatically. However, the right numbers of workers must be provided to handle the flow of block coming from the curing area.

Details on the number of cuber men needed are given later in this Chapter and in Appendix A.

The labor does not have to be skiller or have any technical knowledge of machinery or even the process; but they have to be taught about the cubing task and the importance of keeping up with the rest of the process. Usually, workers become adept at cubing after they learn the pattern of the cubes.

Cubing by hand (at Level B) is done as follows. The cubers receive the block coming on a conveyor from Operation 14. The block is turned over (if required), and laid out in tiers of blocks following a given pattern.

Block Handling Equipment Level of Technology C: Mechanized

At technology Level C the automation diminishes and the operation is mechanized rather than automatic. By "mechanized" it should be understood that the equipment is self-powered but has to be operated and maneuvered by the operator.

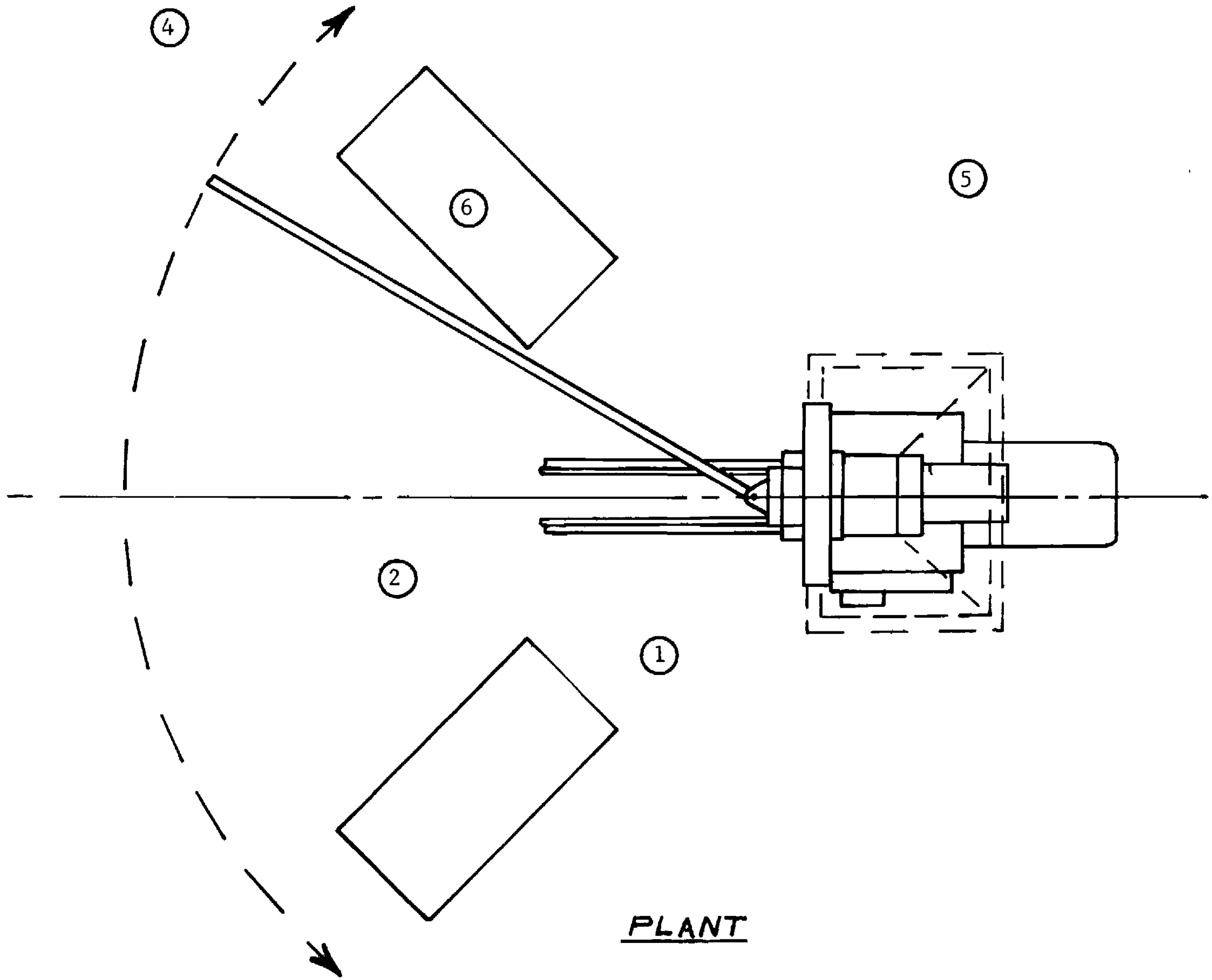
Operations 8 and 13 are not performed automatically; instead, a mechanical device is used and two offbearer men are required. This is the main difference between technology Level B and C.

Operations 10 and 12 are carried out by a fork-lift truck in the same way as at Level B.

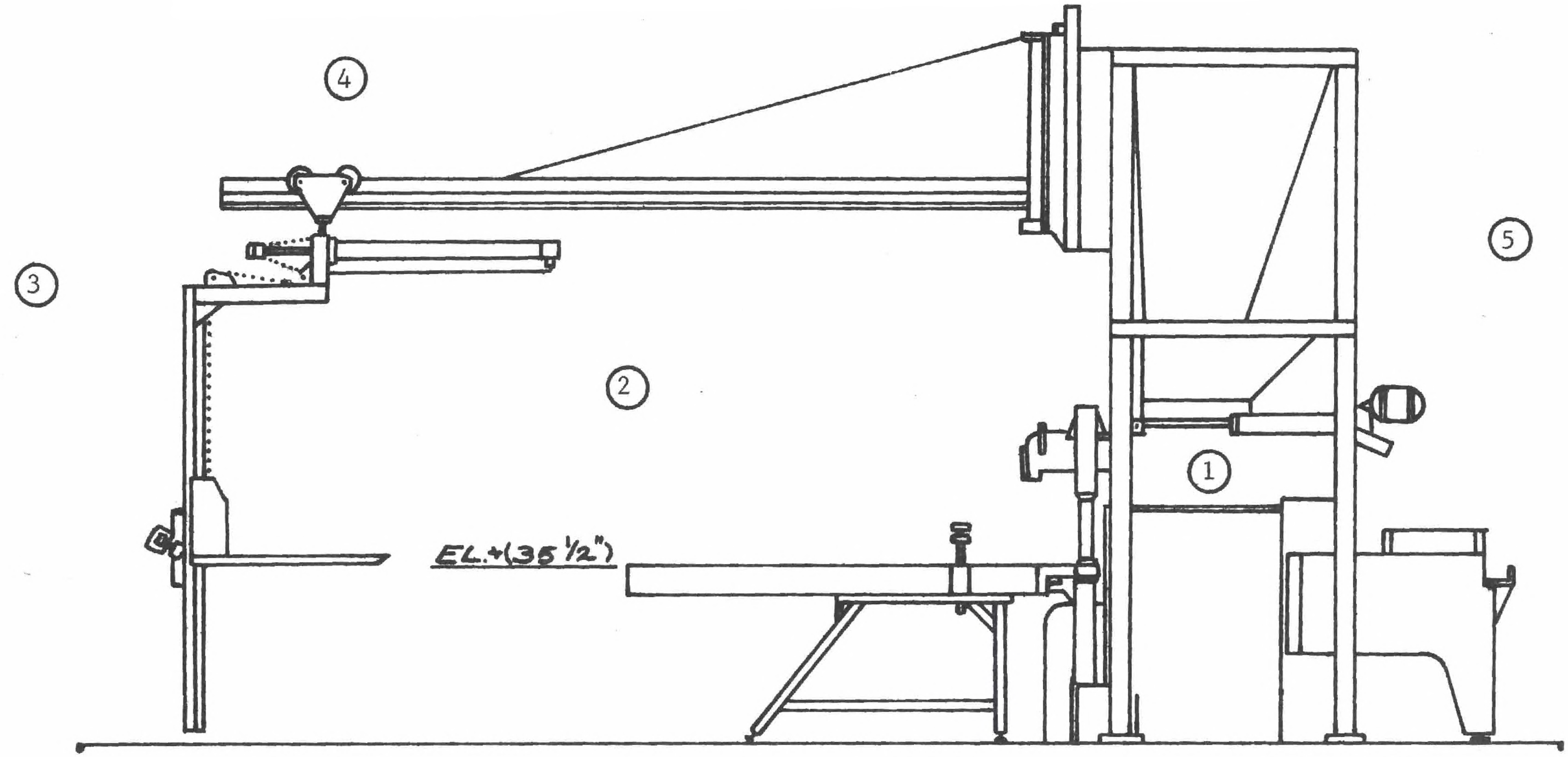
The equipment used at Operations 8 and 13 is a hydraulic offbearing hoist. Figures 3-23 and 3-24 show this aparatus as used to offbear pallets of block from the machine.

The automatic forming machine is adapted to be activated by the offbearer man and run automatically two forming cycles. The two pallets of block produced are picked up by means of the offbearing hoist, and transfered to the rack. The man turns back to the machine to pick up another two pallets of block. The offbearer man learns very soon when to activate the machine in order to find a load of pallets by the time that he turns back to it. In such a way, hopefully, he works as continuously as possible. Since the forming machine is not operated continuously, its capacity is affected greatly.

As in every manual operation, the rate of production depends greatly on the skills of the operators. When this type of equipment is used, the lift-truck operator and the offbearing hoist man at Operation 8 have to be efficient in their tasks to keep the productivity of the automatic forming machine as high as possible. Productivity (full capacity/actual production) of high-capacity automatic forming machines which are designed to operate along with equipment type A or B, is affected to a greater extent than productivity of low-capacity automatic forming machine. The reason is that no matter how good an offbearer is, he will not be able to offbear more than a certain amount of pallets per minute.



PLANT



SIDE

Figure 3-23. Plant and Side Views of Blockmaking Machine and a Hydraulic Offbearing Hoist

1. Machine 2. Delivery Conveyor 3. Hydraulic Offbearing Hoist 4. Boom to Hear Hoist 5. Stand to Support Boom 6. Rack

Design Obtained from Columbia Machine Co.

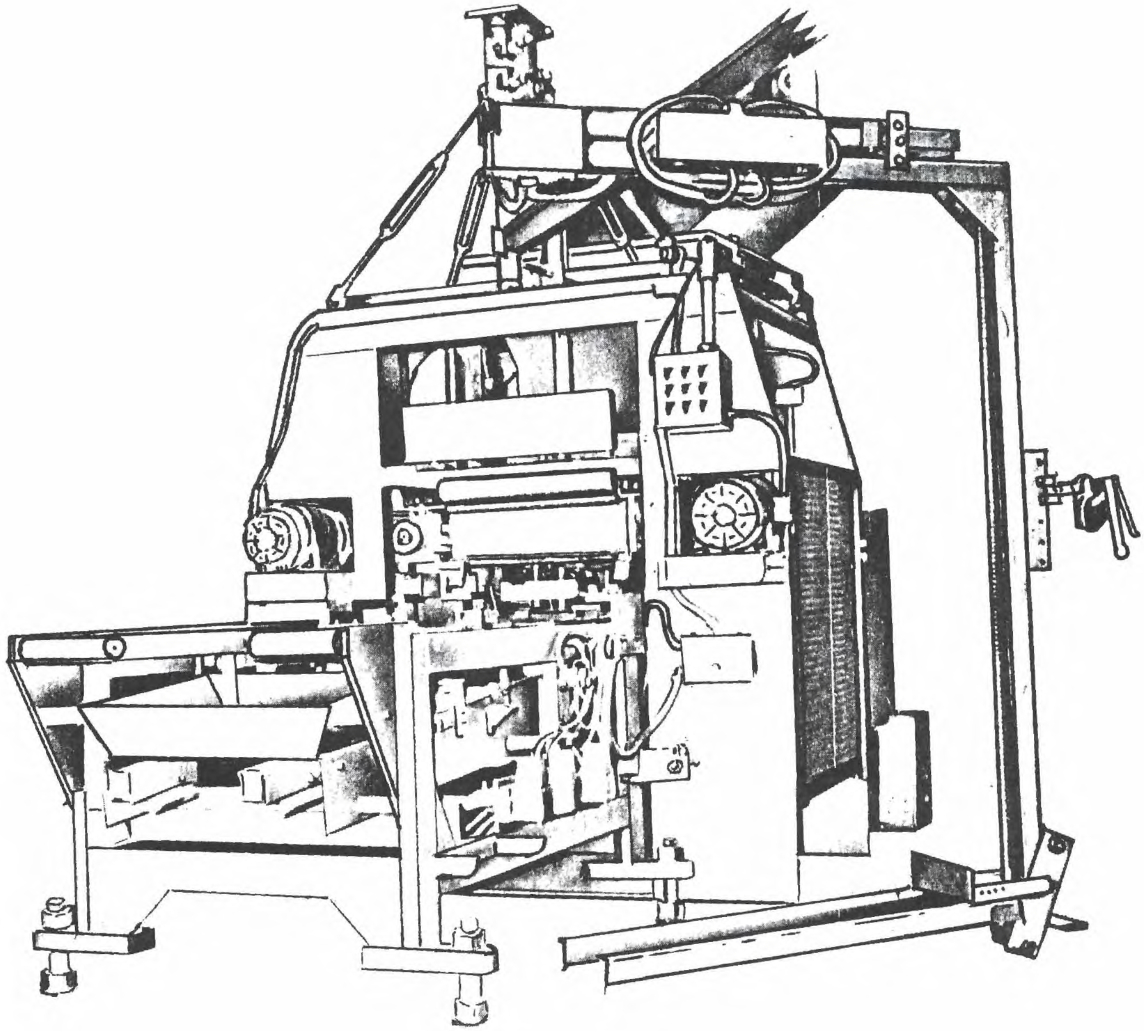


Figure 3-24. Magnetic Offbearer

As the pallets of block come out of the machine the operator moves the hoist towards it, sliding the forks under the pallets. He lifts two pallets at a time, pulls the hoist back rotating to be in position to place the blocks in a shelf of the rack, and turn back to pick another pair of pallets of block.

A standard offbearer like the one shown in Figure 3-23 is known as Non-Magnetic Offbearer and works as just explained. It can be modified and transformed into a Magnetic Offbearer by attaching a magnetic device used to facilitate the task of refeeding pallets into the machine.

When the racks of cured block are unloaded manually the pallets are left on it. As the operator places two pallets of green block on a rack's shelf, he magnetically picks up the two more pallets of green block and drops the empty pallets onto the front pallet magazine.

Picture Courtesy of The Lithibar Co.

It can be safely assumed that a good offbearer man can retire five four-block pallets per minute; six three-block pallets per minute; 5.5 three-block pallets per minute; 6.5 two-block pallets per minute from machines 3, 4, 5, and 6 respectively. In other words, block handling equipment type C decreases productivity of machines 3, 4, 5, and 6 in a 33%, 32%, 17%, and 14% respectively. Machines 7 and 8 are not affected at all because their capacity is low enough to enable the operator to keep up with the production pace.

The operation of this type of equipment is not complicated and workers can learn fast and develop a great skill. Workers do not have to be experienced operators or mechanics. The only machine that requires knowledge of mechanics is the forming machine, which can be attended by the foreman for maintenance and repairs.

In technology Levels A and B, Operations 8 to 14 were classified as automatic and semi-automatic respectively, and then some variants for Operation 15 were included (automatic and semi-automatic for Level A and automatic, semi-automatic, and manual for Level B). These variants bring up two optional setups for technology Level A, and three options for Level B (refer to Table 3-5).

Level C, however, is slightly different. The equipment available for Operations 8 through 13 provide three sub-levels of technology. Consequently, its description is divided in three parts (sub-levels), each representing a variation of the equipment available for Operations 8 and 13. Following each variation, the equipment used for Operations 14, 15, and 16 is discussed (see Table 3-5 for a better understanding of this discussion). The three sub-levels are composed by the following sets:

C_1, C_2, and C_3, first sub-level; C_4, C_5, and C_6, second sub-level; C_7 and C_8, third sub-level.

Even though the variations are important, they are not treated as different levels of technology because they are basically equal, and the same rate of production can be handled with any of the three alternatives.

First Sub-Level (C_1, C_2, and C_3). Operations 8, 10, 12, and 13. Two offbearing hoists are used to carry out Operations 8 and 13, and a fork-lift truck to transport the racks in Operations 10 and 12.

Operation 14. Equipment for stripping blocks from pallets and feeding pallets to machine is semi-automatic at this variation because of the characteristics of equipment for Operations 8 and 13.

The pallets of block are moved on to a conveyor leading to a depalletizer or pushoff device which automatically separates blocks and pallets. The latter are led to a pallet magazine and eventually automatically fed into the forming machine. Figure 3-25 displays a typical layout of this type of equipment.

Operation 15. After stripping the blocks they travel on the conveyor to the cubing area. Semi-automatic and manual equipment can be used at this station. This task is worked as in Level B. Cuber men requirements are specified later in Part 2, and Appendix A.

Operation 16. Either for semi-automatic or manual cubing equipment, the cubes are carried to the yard by a fork-lift truck. However, the yarding operation can be done manually with a special hand truck such as shown in Figure 3-26. In this case the cubes are made small. Twenty four standard blocks per cube is a load that a man can carry by a hand truck of this type.

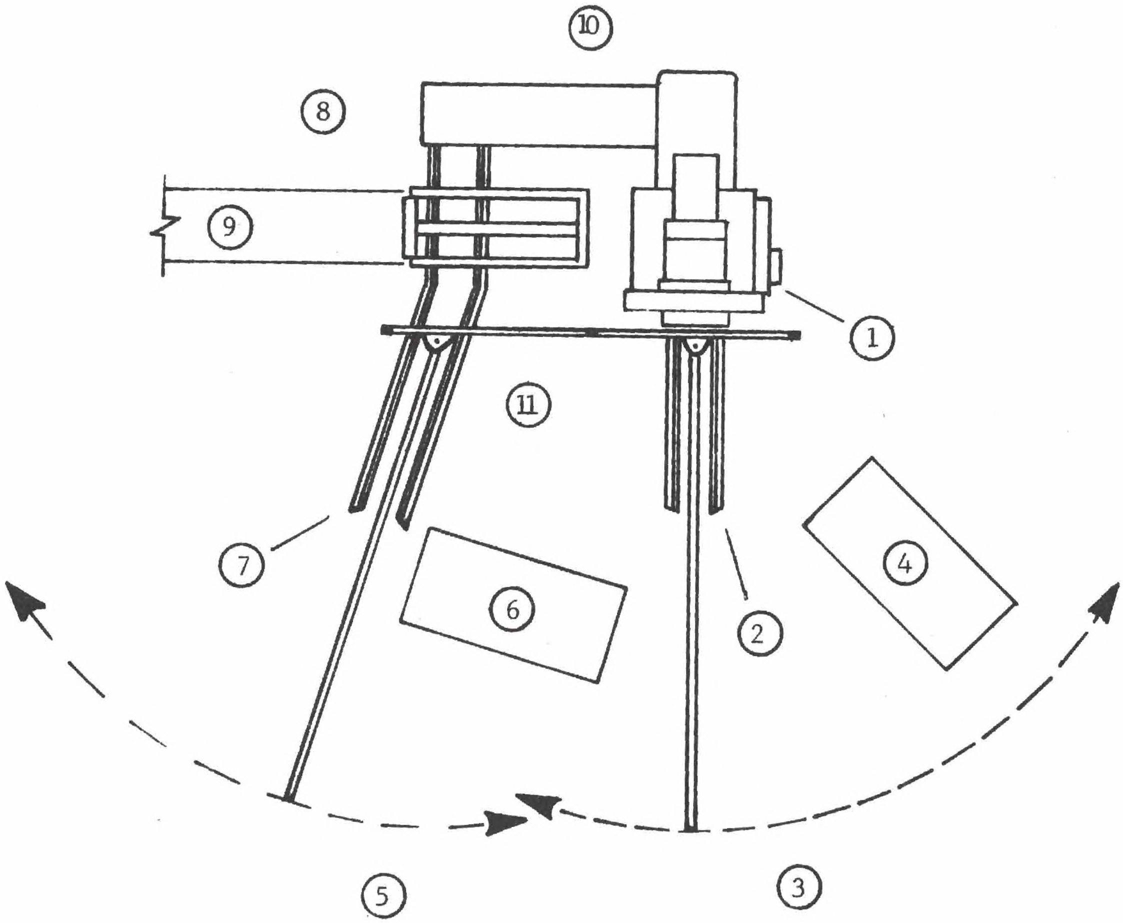


Figure 3-25. Offbearing, Loading, and Unloading System with Two Offbearing Hoist

1. Blockmaking Machine
2. Delivery Conveyor
3. Loading Offbearer
4. Rack to be Loaded with Green Block
5. Unloading Offbearer
6. Rack of Cured Block to be Unloaded
7. Return Conveyor
8. Depalleter (Push-Off Device)
9. Conveyor Leading Block to Cubing Area
10. Pallet Magazine
11. Stand

Design Obtained from Columbia Machine Co.

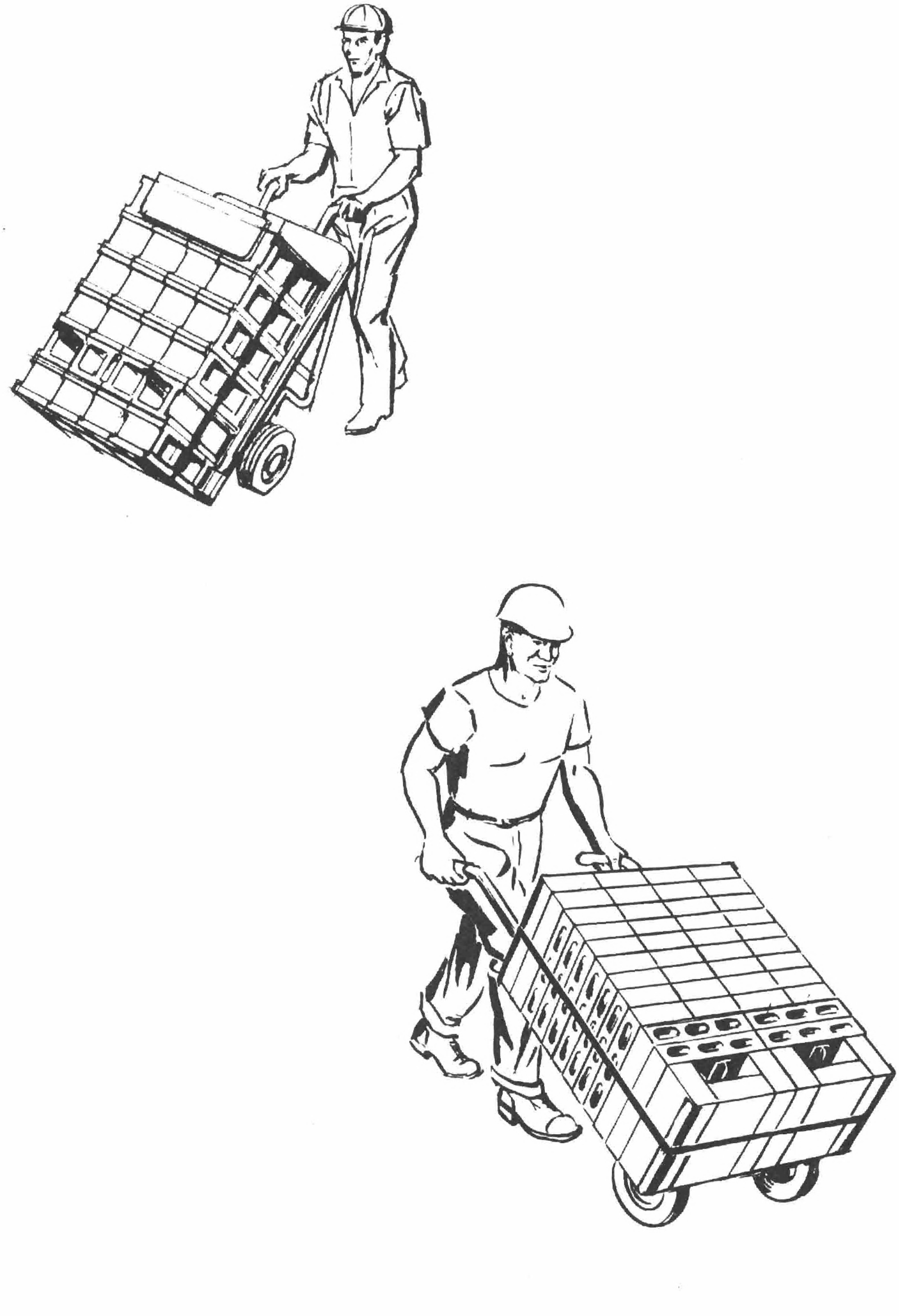


Figure 3-26. Hand Truck

Picture Courtesy of Signode Co.

Second Sub-Level (C_4, C_5, and C_6). Operations 8, 10, 12, and 13. The main difference between this and the variation described above is that the racks are unloaded manually (Operation 13) instead of using a second offbearing hoist. At Operation 13 (unload in-process storage device) only the blocks are unloaded and the pallets remain in the racks.

The labor requirements are discussed in Appendix A.

Operation 14. Depalletizing and feeding pallets to the machine is done mechanically by means of a magnetic offbearing hoist*. The offbearer is practically working two operations at a time (8 and 14).

According to equipment manufacturers this sub-level (C_4, C_5, C_6) is perhaps the most popular set of equipment for Level C (particularly C_5).

Operation 15. Semi-automatic or manual equipment is used for cubing. Cubing is done semi-automatically in the same way as described in the first variation. Nevertheless, manual cubing is done different in this case. To avoid double handling, as the blocks are manually unloaded from the racks (Operation 13) they are laid out in a given pattern to form the cubes.

The number of men required is specified in Part 2 and Appendix A.

Operation 16, yarding, is carried out in the same way as in the first variation.

Third Sub-Level (C_7, C_8). This equipment shifts towards a fully manual operation.

Operation 8, 10, 12, 13. Operations 8 to 13 are performed as described for the second Sub-Level (C_4, C_5, C_6) but the rest of the operation is done manually.

*See explanation about magnetic offbearer on Figure 3-24.

Operation 14. After the blocks are unloaded, the racks (with pallets on) are brought to the forming machine, and the pallets are manually fed to it. Once the rack is empty, it can be reloaded with green blocks and sent to the kilns.

Operation 15. Cubing is made only manually and in the same way as explained in the second sub-level. Fork-lift truck or hand truck yarding method can be utilized.

Block Handling Equipment Level of Technology D: Semi-Mechanized

The equipment classified under this level is the simplest sort to be used with automatic or semi-automatic blockmaking machines. It is quite suitable for manual powered machines and the tamper machine. The block is handled by hand throughout the operation.

Even though Table 3-5 shows only three sets of this type of equipment, the possible layouts are many. Based on experience and arrangement of the site, each manufacturer has his own way to perform the operation. The capacity to handle the output of the automatic or semi-automatic forming machine depends on the skills of the workers and the workers and the method practiced.

Block handling Levels A, B, and C are designed to be used when the curing operation is done in a kiln (steam curing). One of the three sets of equipment shown in Level D is suitable for kiln curing (D_1), and the other two (D_2 and D_3) are suitable for air curing.

In the case of kiln curing the blocks are offbeared (Operation 8) by two men and placed in a rack, which in this case is small (about 30 standard blocks per rack) and designed to be carried to and from the kiln by means of a jack-lift truck (Operations 10 and 12 respectively). The rest of the operation is carried out in the same way as explained in set C_8 above.

The equipment used to handle the block when air curing is adopted is somewhat similar to the fully automatic equipment shown in Figure 3-17. However, it is much simpler. The pallets of block are received by two men (Operation 8) at the machine and transfered onto a special designed cable conveyor. The blocks travel on the conveyor to the yard (Operation 10) where a crew of men, in groups of two, manually pick them up, carrying them and setting them on the ground. After no less than 48 hours, the blocks are cubed and yarded to complete the hardening through about twenty five more days.

Operations 12 and 13 are unecessary and Operations 14 and 15 are done simultaneously at the yard, i.e., while a group of cuber men makes the cubes at the yard, a man picks up the empty pallets and carries them to the machine area.

Operation 16, yarding the cubed blocks, can be done with a fork-lift truck or with a hand-truck; these two choices bring up sets D_2 and D_3 respectively.

Figure 3-27 shows a layout of a plant with equipment of this kind. The figures of labor requirements are presented in Part 2.

Block Handling Equipment Level of Technology E: Manual

This level of technology typifies the method used when blocks are produced with a mold box. The operation is reduced as mentioned before. The blocks are carried by hand to the yard, set on the ground, and after forty eight hours stacked to finish the hardening process.

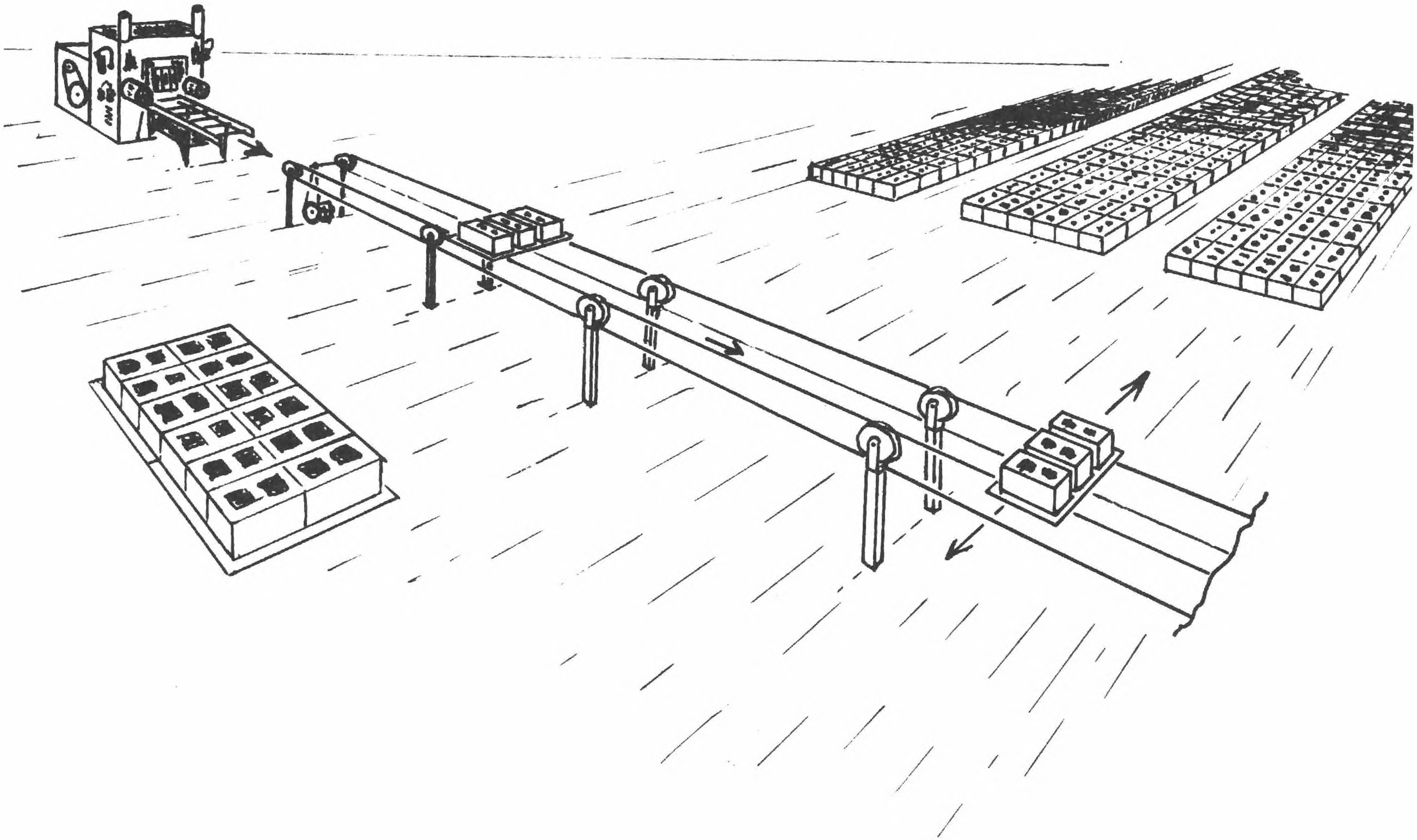


Figure 3-27. Block Handling
Suitable for Air Curing Systems

Part 2. Selection of Blockforming Machine/Block Handling Equipment Combinations

The purpose of the discussion which follows is to furnish data to estimate the capital cost (based on initial cost) and the operating cost (based on labor and power requirements) for the block handling equipment discussed in Part 1. The data presented is based on production output capacity of the blockforming machines discussed above. The reason for this is that in order to handle different production outputs there are several sizes of block handling equipment of the same level of technology, i.e., two automatic blockforming machines with output capacities of 16,000 and 12,500 standard blocks per eight-hour shift can be both equipped with block handling equipment Level A; however, both block handling equipments have different capacity since they are designed for different machines or different rate of output. Thus, in order to produce data that can be used, each forming machine was analyzed along with each suitable type of block handling equipment. For each forming machine the initial cost, and labor and power requirements of a suitable block handling equipment were estimated. Also discussed is the extent to which block handling equipment of each level of technology affects the output of a forming machine.

When all the forming machines were analyzed, data regarding capital and operating costs were available for blockforming machine/block handling equipment combinations for any production output capacity required.

There is something important to discuss about the capacities of the forming machines and overall capacities of combinations. The upper limit of capacity for a forming machine can be established relatively easy based on data from equipment manufacturers and some standards of production established by block producers. However, a lower limit is more difficult to pinpoint.

The production output of a forming machine can be adjusted to any desired level less than its maximum capacity. Many times two plants having the same machine and the same type of block handling equipment, have a different production output. Generally there may be two reasons for this. One of the plants knows and controls the process better than the other, or one of the plants has purposely decreased its production because capacity exceeds demand.

Since there are so many equipment manufacturers the data on costs is an average of the actual cost of equipment of a given capacity and level of technology, since the cost of equipment to handle a given output is different from each manufacturer, cost estimates represent an average cost of equipment classified under a given level of technology.

The data on labor are also estimates. Labor estimates for technology Levels A and B, can be assumed to be true for almost any plant. For lower levels of technology, where manual operations are involved, the labor required depends on factors such as skills of operators, layout of equipment, methodology, etc. Nevertheless, the figures are a good estimation under normal circumstances.

Finally, a rule of thumb has been reasoned to decide the types of block handling equipment that are compatible in capacity with both a given output, or a given forming machine (e.q., block handling equipment of Level C (see Table 3-5) was not deemed compatible with the forming machine No. 2 (see Table 3-1) whose capacity goes up to 16,000 standard units per shift). Such a forming machine has been designed to work along with equipment of Level A or B. Block handling equipment of a lower technology level affects forming machines output dropping it down to 10,000 units per shift or less. There are other forming machines that are cheaper and can be used with lower level block handling equipment to produce close to 10,000 units. Thus, the combination "forming machine No. 2/block handling equipment of Level C", was left out of the analysis. Also small forming machines matched with block handling equipment of high levels of technology were not found congruous and were left out of consideration as well. This rule has its grounds on information and advice obtained from equipment manufacturers and block producers. The sets presented are typical arrangements and layouts of equipment of the same type.

Bearing in mind this introductory discussion, the next pages explain and present the data of our interest. Table 3-6 presents the capacity for each forming machine/block handling equipment combination. The first column contains all the forming machines described above and summarized in Tables 3-1, 3-2, 3-3, and 3-4. The second column shows the levels of technology of block handling equipment that are analyzed along with each machine. The third column indicates the capacity that each combination can reach. Finally, the fourth column indicates, based on Table 3-5, what sets of block handling equipment are analyzed for each capacity.

Table 3-6 is the result of analyzing each forming machine along with its suitable block handling equipment. The analysis is used to

Table 3-6. Capacity of Production for Forming Machines and Their Suitable Types of Block Handling Equipment

	FORMING MACHINE TYPE*	LEVEL OF TECHNOLOGY FOR BLOCK HANDLING EQUIPMENT	CAPACITY	SETS WITHIN LEVELS OF TECHNOLOGY THAT ARE ANALYZED FOR THAT CAPACITY
	1	A	23,000	A_1
	2	A	16,000	A_1, A_2
		B	14,500	B_1, B_2, B_3
	3	A	14,000	A_1, A_2
		B	12,500	B_1, B_2, B_3
		C	9,500	C_1, C_2, C_3, C_4, C_5, C_6
	4	A	12,500	A_1, A_2
		B	11,500	B_1, B_2, B_3
		C	9,000	C_1, C_2, C_3, C_4, C_5, C_6, C_7
AUTOMATIC	5	A	9,000	A_1, A_2
		B	9,000	B_1, B_2, B_3
		C	7,500	C_1, C_2, C_3, C_4, C_5, C_6, C_7
	6	B	7,500	B_1, B_2, B_3
		C	6,500	C_1, C_2, C_3, C_4, C_5, C_6, C_7, C_8
		D	4,500	D_1, D_2, D_3
		E	4,500	E_1
	7	C	4,500	C_2, C_5, C_7
		D	3,500	D_1, D_2, D_3
		E	3,500	E_1
	8	C	2,000	C_5, C_7
		D	1,500	D_1, D_2, D_3
		E	1,500	E_1

Table 3- 6. Continued

FORMING MACHINE TYPE*		LEVEL OF TECHNOLOGY FOR BLOCK HANDLING EQUIPMENT	CAPACITY	SETS WITHIN LEVELS OF TECHNOLOGY THAT ARE ANALYZED FOR THAT CAPACITY
Semi-Automatic	9	C	2,000	C_5, C_7
		D	2,000	D_1, D_2, D_3
		E	1,500	E_1
Powered, Manual	10	D	800	D_1, D_2
		E	800	E_1
	11	D	400	D_1, D_2, D_3
		E	400	E_1
	12	D	200	D_1, D_2, D_3
		E	200	E_1
Manual & Molds	13	D	500	D_1, D_2, D_3
		E	500	E_1
	14	E	120	E_1

*See Tables 3-1, 3-2, 3-3, and 3-4.

establish the production capacity and the technical feasibility of each setup. In addition, based on this analysis, the data on cost of the equipment, labor required, and power requirements were estimated. These data will be discussed below.

Table 3-6 has been transformed into Table 3-7, which gives a better insight of what combinations can be used to achieve a given production output. The combinations are composed of one forming machine and block handling equipment of a given level of technology (it is important to bear in mind that within each level of technology there are several optional sets of equipment offering the same capacity).

The first column of this table presents output capacity, and columns 2 to 29 show the combination of forming machine/block handling equipment. Under these columns it has been indicated the capacity that each setup can reach, i.e., if you need a capacity of 9,000 standard block per shift, across from column one it can be seen that for this output the following sets can be used:

Forming Machine:	Block Handling Equipment Level:
4	C
5	A
5	B

Any other combination from 1/A to 4/A has excess capacity and the wasting of capacity would be costly.

It is important to pinpoint that the figures presented in Tables 3-7 and 3-8 are for combinations of equipment formed by only one forming machine and a suitable set of block handling equipment; consequently, forming machines/block handling equipment combinations of low technology levels offer low production output capacities. This does not mean that high production outputs cannot be obtained with low technology levels. Several equipment combinations of low capacity can operate together to obtain a high overall production output. For example, to produce 9,000 standard units per shift, in addition to the combinations presented above, the following multiple units of lower capacity equipment combinations can be used:

Forming Machine:	Block Handling Equipment Level:	Capacity (Std. Units/Shift):
5	C	7,500
8	C	1,500
	OVERALL CAPACITY	9,000
6	B	7,500
8	C	1,500
	OVERALL CAPACITY	9,000
6 (2)	D (2)	4,500 (2)
	OVERALL CAPACITY	9,000
7 (2)	C (2)	4,500 (2)
	OVERALL CAPACITY	9,000
7 (2)	D (2)	3,500 (2)
8	C	2,000
	OVERALL CAPACITY	9,000
8 (6)	D (6)	1,500 (6)
	OVERALL CAPACITY	9,000
10 (11)	D (11)	800 (11)
11	D	200
	OVERALL CAPACITY	9,000
14 (90)	E (90)	100 (90)
	OVERALL CAPACITY	9,000

The initial cost of block handling equipment suitable for a given machine, labor requirements, and installed power, are given in Tables 3-8, 3-9, and 3-10 respectively, and will be explained below.

Table 3-8, as mentioned, presents the figures of total cost of sets of equipment (within a level of technology) to handle the output of

Table 3-7. Output Capacity of Forming Machine/Block Handling Equipment Combinations

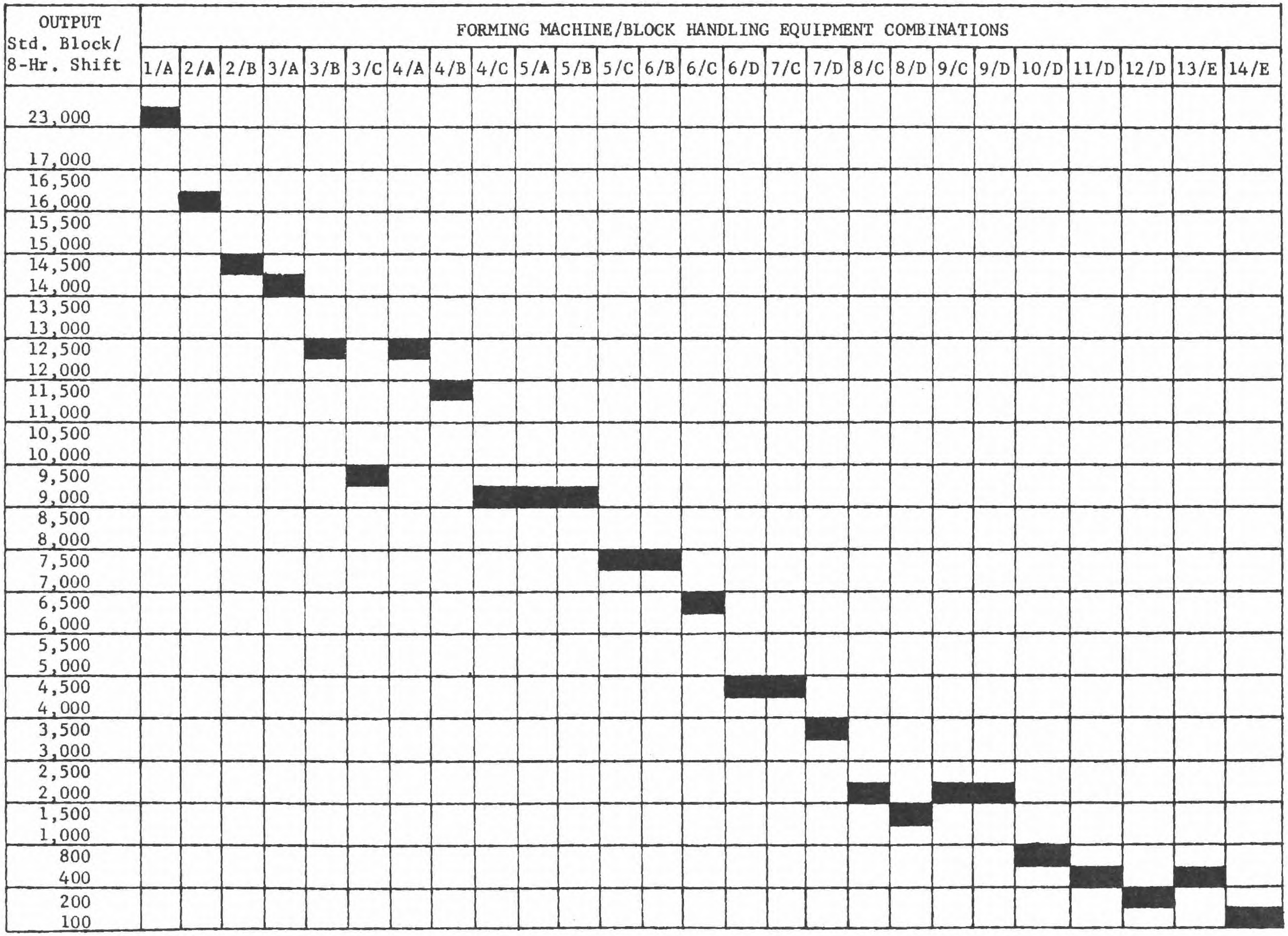


Table 3-8. Total Initial Cost of Block Handling Equipment for the Various Levels of Technology (Thousands of U.S. Dollars)

Forming Machine Type		Block Handling Technology Level																
		A		B			C								D			E
		A_1	A_2	B_1	B_2	B_3	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	D_1	D_2	D_3	E_1
Automatic	1	800	---	---	---	---	---	---	---	---	---	---	--	--	--	--	---	---
	2	460	420	320	280	245	---	---	---	---	---	---	--	--	--	--	---	---
	3	430	395	305	270	230	175	150	120	165	140	130	--	--	--	--	---	---
	4	390	355	270	235	200	160	135	105	150	125	115	83	--	--	--	---	---
	5	300	270	230	200	175	145	120	90	140	115	105	80	--	--	--	---	---
	6	---	---	205	175	155	135	110	90	130	105	100	80	40	20	30	20	---
	7	---	---	---	---	---	---	65	---	---	60	---	50	--	20	30	20	---
	8	---	---	---	---	---	---	---	---	---	35	---	30	--	15	23	15	---
Semi-Auto.	9	---	---	---	---	---	---	---	---	---	35	---	30	--	15	23	15	---
Powered, Manual	10	---	---	---	---	---	---	---	---	---	---	---	--	--	5	--	5	---
	11	---	---	---	---	---	---	---	---	---	---	---	--	--	--	--	2.5	---
	12	---	---	---	---	---	---	---	---	---	---	---	---	--	--	--	1.5	---
Manual Molds	13	---	---	---	---	---	---	---	---	---	---	---	---	--	--	--	---	1.0
	14	---	---	---	---	---	---	---	---	---	---	---	---	--	--	--	---	0.8

a given forming machine.

The first column shows the types of block forming machines, and the rest of the columns present the total cost of sets of block handling equipment within each level of technology.

From Table 3-7, for a given output (9,000 units per shift) the possible "forming machine/block handling equipment"combinations were identified (4/C, 5/B, 5/A). To obtain the cost of each combination Tables 3-1 and 3-8 are used.

For the combination 4/C from Table 3-1 the cost of the automatic forming machine No. 4 is found to be $115,000 U.S. Dollars. To determine the cost of the sets of block handling equipment of technology Level C suitable for this machine, Table 3-8 is used. The line for blockforming machine No. 4 and the column for block handling equipment technology Level C are found; the intersection of line and columns give the figures needed:

$160,000 for C_1
135,000 for C_2
105,000 for C_3
150,000 for C_4
125,000 for C_5
115,000 for C_6
or 80,000 for C_7

The total cost of the combination 4/C is $115,000 plus the cost of either alternative of block handling equipment Level C.

In the same way the cost for combinations 5/B and 5/A can be calculated.

The data of labor required can be obtained from Tables 3-9 and 3-9'. The former contains the figures for labor required to operate equipment type A and B, except set B_3. The latter presents the labor

Table 3-9. Labor Requirements for Blockforming Machine/Block Handling Equipment Combinations of Technology Levels A and B (except Set B_3)

Tech. Level	Set of Equipment	Machine Operator	Offbearing Hoist Man	Offbearer Man	Lift-Truck Operator	Hand-Truck Man	Cuber Operator	Cubing Man	Pallets Man
A	A_1	1	-	-	1	-	-	-	-
	A_2	1	-	-	1	-	1	-	-
B	B_1	1	-	-	2	-	-	-	-
	B_2	1	-	-	2	-	2	-	-

Table 3-9'. Labor Requirements for Blockforming Machine/Block Handling Equipment Combinations of Technology Levels C, D, & E and Set B_3

Tech. Level	Set of Equipment	Machine Operator	Offbearing Hoist Man	Offbearer Man	Lift-Truck Operator	Hand-Truck Man	Cuber Operator	Cubing Man	Pallets Man
FORMING MACHINE 2									
B	B_3	1	-	-	2	-	-	9	-
FORMING MACHINE 3									
B	B_3	1	-	-	2	-	-	8	-
C	C_1	-	2	-	2	-	1	-	-
	C_2	-	2	-	2	-	-	6	-
	C_3	-	2	-	1	3	-	6	-
	C_4	-	1	5	2	-	1	-	-
	C_5	-	1	-	2	-	-	8	-
	C_6	-	1	-	1	3	-	7	-

Table 3-9'. Continued

Tech. Level	Set of Equipment	Machine Operator	Offbearing Hoist Man	Offbearer Man	Lift-Truck Operator	Hand-Truck Man	Cuber Operator	Cubing Man	Pallets Man
				FORMING MACHINE 4					
B	B_3	1	-	-	2	-	-	8	-
	C_1	-	2	-	2	-	1	-	-
	C_2	-	2	-	2	-	-	5	-
	C_3	-	2	-	1	3	-	5	-
C	C_4	-	1	4	2	-	1	-	-
	C_5	-	1	-	2	-	-	7	-
	C_6	-	1	-	1	3	-	7	-
	C_7	-	1	-	2	-	-	7	2
				FORMING MACHINE 5					
B	B_3	1	-	-	2	-	-	6	-
	C_1	-	2	-	2	-	1	-	-
	C_2	-	2	-	2	-	-	5	-
	C_3	-	2	-	1	2	-	5	-
C	C_4	-	1	4	2	-	1	-	-
	C_5	-	1	-	2	-	-	7	-
	C_6	-	1	-	1	2	-	7	-
	C_7	-	1	-	2	-	-	7	1

Table 3-9'. Continued'

Tech. Level	Set of Equipment	Machine Operator	Offbearing Hoist Man	Offbearer Man	Lift-Truck Operator	Hand-Truck Man	Cuber Operator	Cubing Man	Pallets Man
				FORMING MACHINE 6					
B	B_3	1	-	-	2	-	-	5	-
	C_1	-	2	-	2	-	1	-	-
	C_2	-	2	-	2	-	-	4	-
	C_3	-	2	-	1	2	-	4	-
C	C_4	-	1	4	2	-	-	1	-
	C_5	-	1	-	2	-	-	6	-
	C_6	-	1	-	2	2	-	6	-
	C_7	-	1	-	2	-	-	6	1
	C_8	-	1	-	1	2	-	6	1
	D_1	-	-	2	-	3	-	3	1
D	D_2	-	-	2	1	6	-	3	1
	D_3	-	-	2	-	9	-	3	1
				FORMING MACHINE 7					
	C_2	-	2	-	1	-	-	3	-
C	C_5	-	1	-	1	-	-	4	-
	C_7	-	1	-	1	-	-	4	1
	D_1	-	-	2	-	2	-	3	1
D	D_2	-	-	2	1	5	-	3	1
	D_3	-	-	2	-	7	-	3	1

Table 3-9'. Continued

Tech. Level	Set of Equipment	Machine Operator	Offbearing Hoist Man	Offbearer Man	Lift-Truck Operator	Hand-Truck Man	Cuber Operator	Cubing Man	Pallets Man
				FORMING MACHINE 8					
C	C_5	-	1	-	1	-	-	2	-
	C_7	-	1	-	1	-	-	2	1
D	D_1	-	-	2	-	2	-	2	1
	D_2	-	-	2	1	2	-	2	1
	D_3	-	-	2	-	4	-	2	1
				FORMING MACHINE 9					
C	C_5	-	-	2	1	-	-	2	-
	C_7	-	-	2	1	-	-	2	1
D	D_1	-	-	2	-	2	-	2	1
	D_2	-	-	2	1	1	-	2	1
	D_3	-	-	2	-	3	-	2	1

Table 3-9'. Continued

Tech. Level	Set of Equipment	Machine Operator	Offbearing Hoist Man	Offbearer Man	Lift-Truck Operator	Hand-Truck Man	Cuber Operator	Cubing Man	Pallets Man
FORMING MACHINE 10									
D	D_1	-	-	1	-	1	-	1	-
	D_3	-	-	1	-	2	-	1	-
E	E_1	-	-	1	-	2	-	1	-
FORMING MACHINE 11									
D	D_3	-	-	2	-	0.5	-	0.5	-
E	E_1	-	-	2	-	2	-	1	-
FORMING MACHINE 12									
D	D_3	-	-	1	-	0.5	-	0.5	-
E	E_1	-	-	1	-	1	-	1	-

requirements for equipment type C, D, E, and set B_3.

Since the Stages II and III of the process are performed together, the data of labor includes the forming machine operator.

For Levels A and B (except set B_3), because of the automation involved, the amount of labor needed is always the same regardless of the forming machine or rate of production.

Table 3-9 presents the number and type of labor usually needed to operate automatic or semi-automatic equipment. Columns one and two present the levels of technology A and B, and the sets of equipment within each of them respectively. Columns three to ten are labeled with terms that typify the skills needed. This terminology is defined in the following lines.

Mechanic Operator. In addition to the operation of automatic equipment, this job requires capability to give periodic maintenance and repairs of equipment when needed.

Offbearing Hoist Man. This job does not require knowledge on mechanics. The offbearing hoist operation consists on receiving the pallets of block, loading the racks, and controlling the forming machine. The importance of this job has been explained before.

Offbearer Man. This job consist on receiving the pallets of block from the forming machine, loading the racks or the hand-truck, or transfering the pallets of block unto the cable conveyor, and controlling the forming machine.

Fork-Lift Truck Operator. Skills to operate a conventional fork-lift truck are required. Its importance has also been discussed earlier.

Hand-Truck Man. Laborer to carry pallets of block from cable conveyor to yard, to carry small racks to the kiln by means of a jack truck, and to carry small cubes to the yard.

Cuber Operator. This job requires skills to operate an automatic or semi-automatic cuber. A simple training is required to learn and qualify for this job.

Cubing Man. Laborer able to manually form cubes of block. This task can be learnt in a few days. Requires no skills on machinery at all.

Pallets Man. Its function is to bring the pallets to the forming machine and place them into the pallet magazine.

Since manual operations are involved in Levels C, D, and E, and set B_3, the labor requirements change as the output changes. To present the labor requirements in a congruent way, based on each machine and a given set of block handling equipment, the number of workers needed are presented in Table 3-9'. This table is based on the outputs indicated in Tables 3-6 or 3-7.

It is worthwhile to mention that five persons at Level A are not equivalent in terms of labor cost to five persons at Level D. At Level A or B the people are experienced, while at Levels C or D not all the workers are supposed to be skilled. This will be discussed more fully in Chapter VI.

From the example of page 85, the labor requirements to operate the forming machine No. 4 along with each optional set of block handling equipment (Level C) are:

Forming Machine	Set of Block Handling Equipment	Total Men
4	C/1	5
4	C/2	9
4	C/3	11
4	C/4	8
4	C/5	10
4	C/6	12
4	C/7	12

Finally the data on power is presented in Table 3-10. It has the same form as Table 3-8, but the figures stand for the horsepower installed in the equipment. The table includes only automatic and semi-automatic forming machines and levels of technology A, B, and C. The other machines and Levels D and E consume no energy.

To obtain horsepower requirements for each combination the horsepower usually installed in each of the components was summed.

It can be seen in Table 3-10 that for the levels A, B, C, and the forming machines 2, 3, and 4, all have the same horsepower requirements. The same happens with other sections of the table. The reason is that the motor installed in the equipment is about the same size and the sum of horsepower is very close. Obviously since machine No. 2 will handle more blocks, it will consume more energy than No. 3 or No. 4. This has to be adjusted as follows to calculate the kilowatts-hr. consumed: for machines 2, 3, and 4 the utilization factor will be assumed to be 80%, 75%, and 60% respectively. For machines 5, 6, and 7 it will be 75%, 70%, and 70% respectively. For smaller machines 75% will be assumed.

Table 3-10. Total Horsepower for the Block Handling Equipment on the Various Levels of Technology

	Forming Machine Type	Available Equipment Technology Level												
		A		B			C							
		A_1	A_2	B_1	B_2	B_3	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
Automatic	1	80	--	--	--	--	--	--	--	--	---	---	---	---
	2	70	60	53	43	28	--	--	--	--	---	---	---	---
	3	70	60	53	43	28	23	10	10	20	5	3	---	---
	4	70	60	53	43	28	23	10	10	20	5	3	3	---
	5	60	50	40	35	25	17	7	7	15	4	2.5	2.5	---
	6	--	--	40	35	25	17	7	7	15	4	2.5	2.5	2.5
	7	--	--	--	--	--	--	7	--	--	4	---	2.5	---
	8	--	--	--	--	--	--	--	--	--	2.5	---	2.5	---
Semi-Auto.	9	--	--	--	--	--	--	--	--	--	2.5	---	2.5	---

CHAPTER IV

THE CURING STAGE OF THE CONCRETE BLOCK PROCESS

In this chapter the curing stage of the process is discussed. Curing is a term used to indicate the treatment of concrete during the period between stripping from the mold and the time when it is strong enough to be used.

The strength of the concrete is directly affected by the humidity and temperature conditions existing during the curing period. The hardening is due to the hydration of cement, and will continue at a diminishing rate for an indefinite period as long as moisture is present and the temperature is favorable. However, maximum strength with ordinary Portland Cement is, for practical purposes, reached in six months, while about 80% of the six month's strength is reached in three months, and about 60% at twenty eight days. These hardening periods are much reduced when rapid-hardening Portland and high-alumina cements are used. Moisture should be present during the whole period after mixing until the concrete attains a strength sufficient for the requirements for which it is made.

The curing treatments used in the concrete block industry are three: air curing, low-pressure steam curing, and high-pressure steam curing. The highlights of each method will be presented as well as the equipment available for them. A list of references is provided for the reader to investigate and study deeper any aspect of his interest or concern.

The theory of low-pressure and high-pressure steam curing treatments is based on the Manual of Concrete Practice (Part 3) published by the American Concrete Institute. This manual is based on the investigation and findings of experts and the experience of block manufacturers.

Technology of Treatments for Curing

Air Curing System

The term "air curing," as used in this paper, refers to block curing under natural environmental conditions of heat and humidity. The most common practice of this method is outdoor curing; however, under certain circumstances indoor curing may be necessary.

Both outdoors and indoors air curing treatments can be used to achieve satisfactory strength on the block after 28 days; however, a uniform color of the production is difficult to achieve due both to the difficulty of keeping the blocks evenly wet, and allowing them to dry under exactly the same circumstances. In addition, because of the amount of handling needed some cracked and broken blocks result.

Outdoor Air Curing

The time necessary for the block to reach the required strength varies from two to four weeks depending on the type of concrete used. As the blocks are produced they are transfered (on pallets) to the yard and laid out on the ground.

If there is no rain during the curing period the blocks should be watered every day by sprinkling through a hose or from a can. Care should be taken in the early days that there is no sufficient force behind the water to injure the walls of the blocks; a rose or sprinkler hose can be used for this purpose. Newly made blocks should not be left unprotected out of doors during heavy rain because raindrops would cause pitting of the surfaces. On days when there is a good shower of rain to which the blocks are exposed no other watering may be necessary.

The block manufacturer should not let the watering of the products to random showers, since this practice always leads to poor hardening of concrete. The products should be protected from drying winds and sun which would dry out the moisture necessary for proper hardening. In hot or dry weather a good practice is to cover the blocks with sacking, straw, or other material which can be kept wet. In addition to protecting the blocks from drying out, and keeping a wet environment for the products the covering will retain underneath much of the heat received from the sun and the heat released from the hydration of cement. This would be beneficial since, as in every chemical reaction, higher temperatures accelerate the hydration of cement and consequently the hardening process.

The blocks can be handled and stripped from their pallets to be cubed 48 hours after forming. Air curing requires an extensive area if the output is considerable. By cubing the blocks after they are partially cured a lot of space is saved. Most of the time this practice is necessary both for the economy of space and to avoid long walking distances while carrying the blocks from the forming machine to the yard. In addition, by cubing the blocks the pallets can be reused more frequently, representing less pallets necessary for the production and consequently a smaller investment.

Once the blocks have been cubed, special care must be taken to ensure that the units in the center of the cubes are watered. If the cubes are covered for best results it is necessary to remove the covering when water is applied and to ensure that as much as possible of the surface of the concrete is thoroughly wetted before the covering is replaced. If the water does not reach the products in the center of the cubes these units will not reach maximum strength.

Indoor Curing

Indoor curing is necessary in the winter in regions where temperatures drop down to freezing, it is not as necessary in regions where the weather is rather warm or mild. Freezing temperatures stop the hardening and are detrimental to the properties of the finished products.

The simplest method is to keep the products in a room or shed in which the winter temperatures can be kept, by braziers or other means, at about 65°F and not allow to fall below 50°F. It is desirable to avoid a dry heat and this may be done by placing pans of water over the fires so that the atmosphere will keep as much moisture as possible or by flooding the floor with water. In severe weather the products should be kept in such a shed for five days and kept moist all the time by sprinkling daily or more often if necessary. Doors and windows must remain closed as long as possible to avoid a drafty environment. Drafts will tend to dry out the surface of the products, whereas the objective should be to allow the blocks to dry out slowly and uniformly throughout.

After five days under cover, there should be no danger from frost if the products are placed outdoors. The blocks can be cubed at this stage and should be kept moist for five more days; then allowed to dry to complete the curing cycle.

Low-Pressure Steam Curing System

The primary purpose of steam curing is to accelerate strength development so that pallets and racks can be reused at frequent intervals, and the blocks can be stored or put into use at an early age.

Pallets and racks represent a high percentage of the block handling equipment investment and frequent reuse is essential to economical production. Accelerated curing permits earlier delivery of the finished blocks and allows operation at a smaller inventory that is possible with air curing at normal temperatures.

In addition, steam curing yields a product of lighter color than normally obtained with curing at lower temperatures (air curing), resulting in better appearance of the product. Due to simplified handling less culls are obtained in the production.

It offers also the possibility of easy installations of equipment for "quick curing" (total-curing) by application of artificial drying for removal of excess moisture from the blocks soon after they have reached the desired strength.

It is not enough for a block manufacturer to use steam curing, he must know how the steam affects the hardening of the blocks. Frequently it is assumed that all that is necessary is to turn steam into the kiln and continue to inject steam until it is time to empty the kiln. Only then the steam is turned off. Careful study and investigations of steam curing indicates that excellent results can be obtained economically if the block manufacturer understands what is happening in the kiln.

Curing by steam is accomplished by supplying heat and moisture to the concrete blocks. Moisture is required for cement hydration at any temperature; while heat raises the temperature of the units to accelerate the chemical reaction of cement (hydration) and brings about faster hardening.

The term "steam curing" means curing with saturated steam at an atmospheric pressure and temperatures below 212°F (100°C). It is refered to as either low-pressure or high temperatures steam curing. Throughout the discussion the term "temperature" refer to the ambient conditions in which the units are cured, otherwise, it will be specified.

Scheduling the curing is a very important part of the operation to obtain good results. The steam curing of concrete block includes the following periods as stated in the American Concrete Institute, Committee 517. (66, p. 20)

> 1. Presteaming Period: A period of delay between the completion of molding of the product and application of steam. During this period some hydration of the cement occurs and provides some stability to the product prior to exposure to steam. This has also been referred as "holding," "Preset," or "delay" period.

It has been observed that concrete units can be damaged by suddenly introducing them to higher temperatures. It has been suggested (61) that the blocks should not reach a temperature of 120°F for at least two hours after forming.

> 2. Temperature Rise Period: The period during which the temperature of the product is raised at a controlled rate to the desired maximum. The rate of temperature rise is 20°F to 60°F per hour depending on the product, and so requires one to six hours.

The length of presteaming period and the rate of temperature rise are closely related. Low rates of temperature rise (20°F per hour or less) may be used immediately after the units are formed; high rates, however, may be used only after a suitable presteaming period. It is advised by most experts to adopt lower rates for better results which also offers a more economical method of operation since a smaller steam generator can be used than if a higher rate is adopted.

A common practice is to raise the temperature after a suitable presteaming period at a rate not higher to 60°F per hour. It has been observed (43) that variations in rates of temperature rise within a range of 12°F to 48°F per hour have little effect on the compressive strength of the blocks. Other investigators (41) composed two rate of 40°F and 60°F per hour and found not detrimental to strength when preceded by a properly established presteaming time and temperature; but suggested 40°F per hour since the rate of 60°F per hour appeared to approach the safety limit.

> 3. Period at Maximum Temperature: The period during which strength of the product increases to the required level for handling or delivery. This generally requires several hours during which the ambient temperature is held at a constant level. In lieu of this period, it is common practice in the concrete masonry industry to use the "soaking period."

It has been agreed by several investigators (61, 14, 33, 32) that the best results are obtained when the concrete is cured at temperatures between 150°F and 180°F. NCMA (National Concrete Masonry Association) recommends that in the absence of other data an efficient maximum steam curing temperature for concrete blocks of normal weight aggregates be assumed 150°F-165°F, and that for light weight 170°F-180°F.

Usually in the concrete block industry to determine the maximum curing temperature the principle based on equilibrium temperature is applied. Equilibrium is reached when the concrete block and kiln air temperatures are equal. During the temperature rise period the block heats up slower than the kiln atmosphere (see Figure 4-1), but eventually the temperature of the block exceeds that of the kiln. As long as the temperature of the block stays below than the temperature of the surrounding atmosphere, there is a condensation on the surface of the block resulting in a gain of moisture. When block temperature exceeds the kiln temperature, the concrete will begin to loose moisture.

Whether a soaking or constant temperature period is used, the block reamins hotter than the kiln air and continues to loose moisture throughout this period (41).

Equilibrium temperatures can be determined by observing kiln temperature and block weight change; or temperature during the temperature rise period. It varies with kiln type and size, aggregate type, heat loss, etc. Each producer shall established its own.

> 4. Soaking Period: A period after the product has reached maximum temperature during which the steam is shut off and the product is allowed to "soak" in the residual heat and moisture of curing kiln.

Most concrete block plants use soaking instead of continued steaming to maintain maximum steam curing temperature.

It has been observed (43, 77, 87) that by soaking after maximum temperatures the strength of blocks is more favorable than that of units cured at constant temperature.

Blocks are usually soaked overnight, 12 to 18 hours, so that the total cycle of charging, presteaming, soaking, and unloading of kiln is accomplished within a 24 hour period. Practical and economical considerations require reuse of curing facilities each 24 hours.

Even though there is evidence to indicate that fresh concrete block

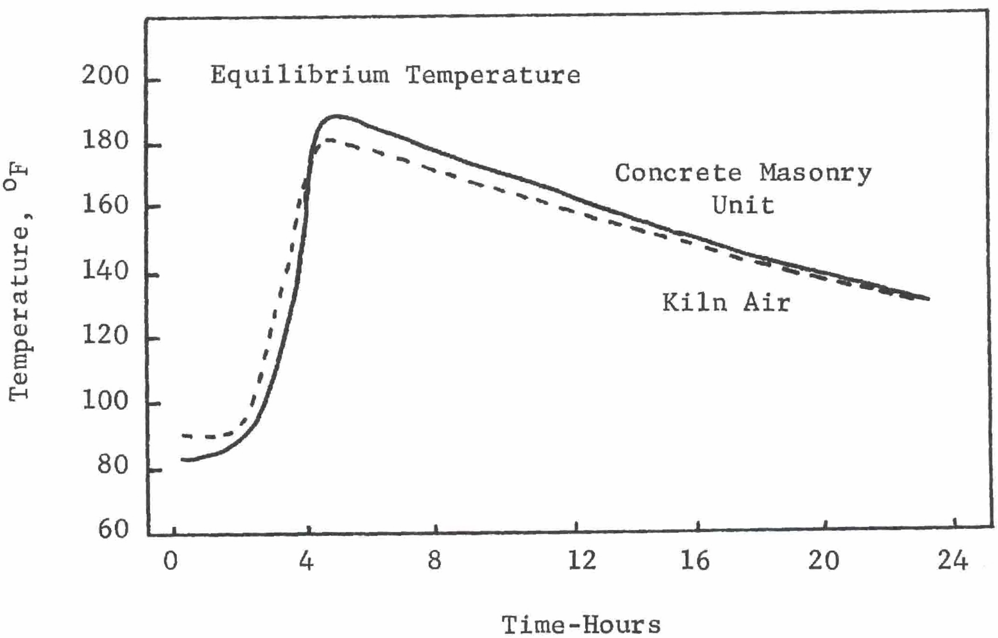


Figure 4-1. Equilibirum Temperature and Lag of Block Temperature During Heating Period*

*Low-Pressure Steam Curing Reported by ACI Committee 517, J.J. Shideler (p. 34).

should not be exposed to rapid temperature rise, there is no published information indicating that rapid cooling of the units after curing is harmful.

Table 4-1 which was presented by the American Concrete Institute* in its 66th Annual Convention, in April 16 of 1970 in New York, N.Y., and reaffirmed in 1976, shows a summary of recommended practice of steam curing for masonry units. Figure 4-2 shows a typical steam curing cycle.

Once the blocks are retired from the kiln they are cubed and yarded to complete the curing treatment through at least seven more days before delivery. This time is less when fast hardening Portland Cement is used.

As mentioned before, the blocks can be artificially dried by removal of excess of moisture. By doing this the blocks can be delivered as soon as they are removed from the kiln. As a general recommendation, concrete block producers interested in this "quick cure" process are advised to investigate thoroughly the system prior to installation (35).

These "quick curing systems" include two more periods than the regular steam curing system. After the units have passed through 1) presteaming period, 2) temperature rise period, and 3) maximum temperature and/or soaking period, they are submitted to 4) drying and carbonation period and finally 5) to venting period.

Blocks cured by this method have high early compressive strength requiring as much as 10% less cement to obtain early strength requirements. The units can be delivered directly from the kilns to the job. Figure 4-3 show a typical curing and drying cycle for total-curing.

*Recommended Practice for Atmospheric Pressure Steam Curing of Concrete (ACI 517-70), American Concrete Institute, Manual of Concrete Practice, Part 3.

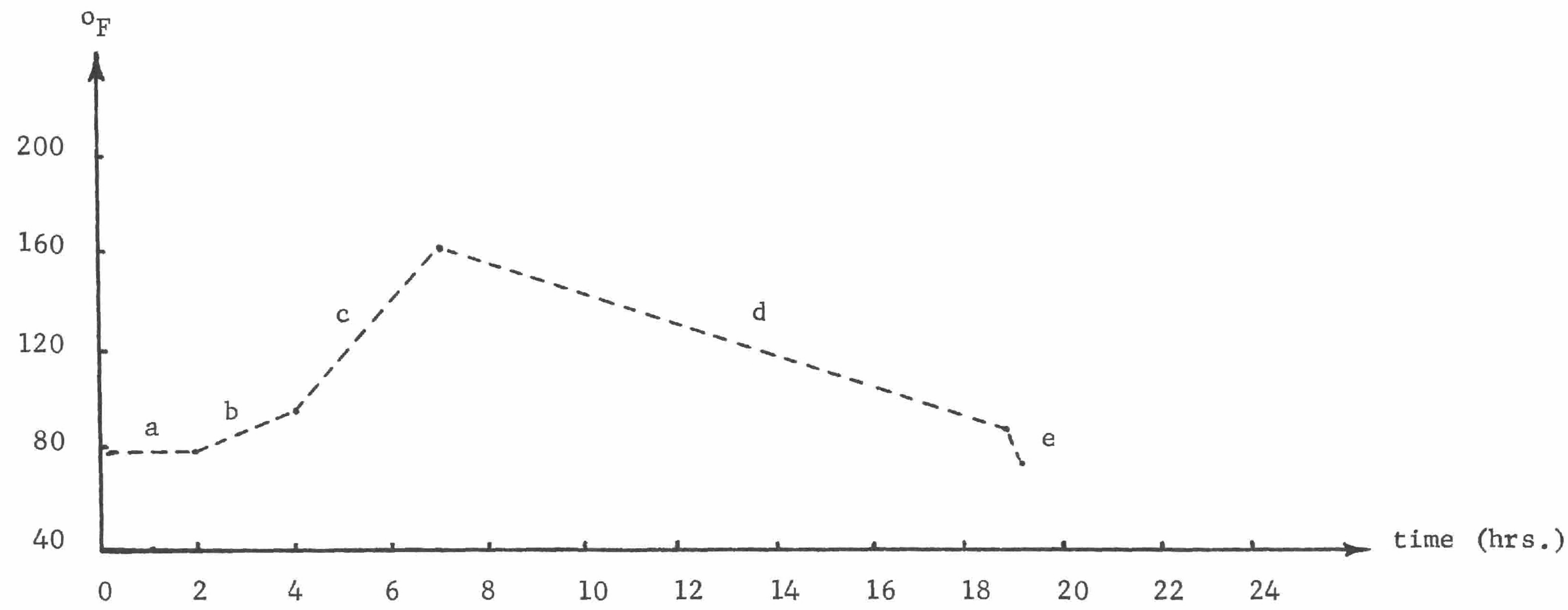


Figure 4-2. Steam Curing Cycle

a. Filling the Kiln
b. Presteaming Period (Temperature rises slightly because of the Heat of Hydration).
c. Steaming or Temperature Rise Period
d. Soaking Period (It can vary from a minimum of 12 hours to 18 hours).
e. The Kiln is opened to exahust the Heat and empty it.

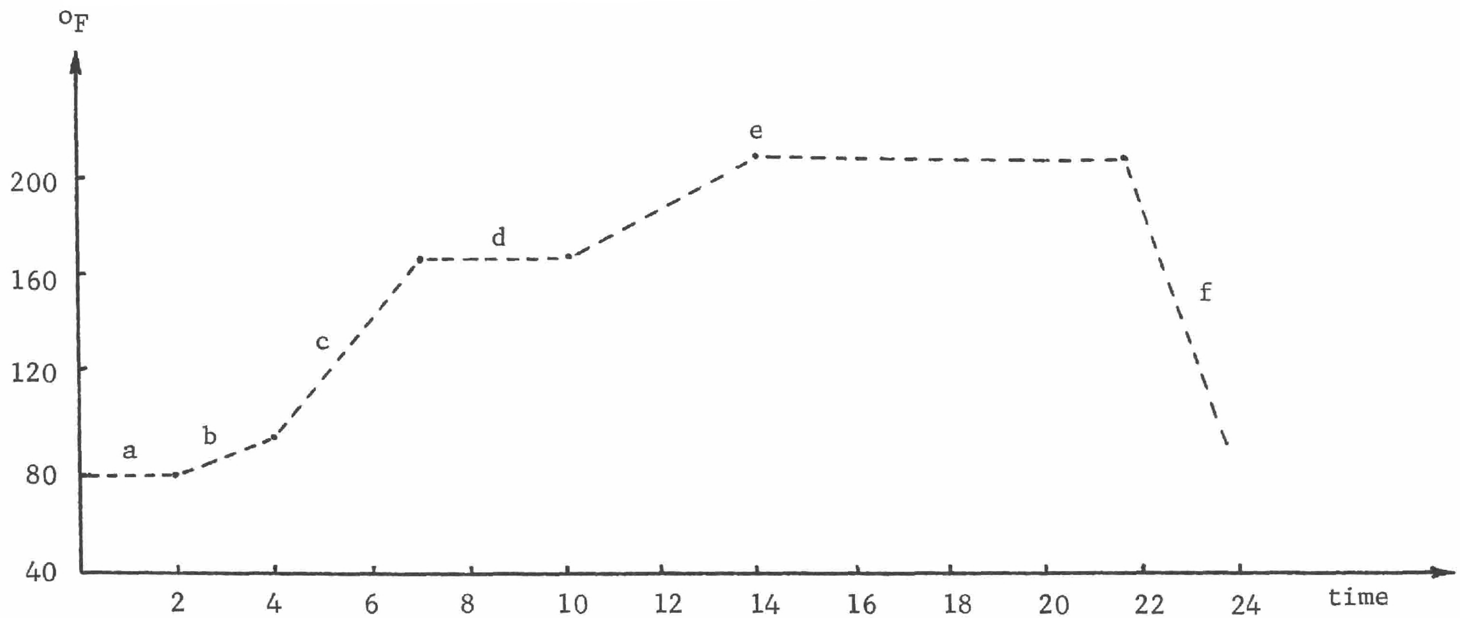


Figure 4-3. Total-Curing System: Steaming, Drying, Carbonation, and Venting

a. Filling the Kiln
b. Presteaming Period
c. Steaming at Temperature Rise Period
d. Constant Temperature Period
e. Drying and Carbonation Period
f. Exhausting Period

Table 4-1. Steam Curing Cycles for Masonry Units

Curing Period	Time, Hr.	Temperature or Rate of Temperature Change	
		^{o}F	^{o}C
Presteaming (Note 1):			
Lightweight Block	1 Minimum	60-100	16-38
Normal Weight Block	2 Minimum	60-100	16-38
Temperature Rise		40-60 per Hr.	22-23 per Hr.
Maximum Temperature (Note 2):	12 (Minimum) for combined Maximum Temperature plus Soaking Periods (Note 3)		
Lightweight Block		180-190	82-88
Normal Weight Block		150-165	66-74
Soaking (Note 3):		$5^{o}F$ per Hr. Maximum Average Decline	$2.8^{o}C$ per Hr. Maximum Average Decline

Notes: 1. Increase presteaming time one hour when ambient temperature is below $32^{o}F$ ($0^{o}C$).

2. When pozzolans are employed as part of the cementing medium, maximum temperatures of $200^{o}F$ to $210^{o}F$ (93^{o}-$99^{o}C$) should be investigated for both lightweight and normal weight aggregate units.

3. The curing cycle may include a "soaking" or a constant "maximum temperature" period, but need not include both. Soaking plus maximum temperature time should total twelve hours minimum. Soaking time may be reduced by an amount of time equal to the time at maximum temperature.

Steam curing has some effects on physical properties of concrete. The effect on compressive strength is briefly discussed below and the lector is encouraged to refer to the list of references for a more complete analysis and other effects such as tensile and flexual strengths, modulus of elasticity, volume changes, durability, permeability. (32, 41, 77, 87, 43, 33, 55, 14, 69, 38, 15, 60, 64, 65, 84, 80, 86) The primary benefit of low pressure steam curing is the rapid strength gain which it imparts to the block. If the proper procedure is followed more than 60% of the moist cured (at 73°F or 23°C) twenty eight-day compressive strength may be obtained in twenty four hours.

On the other hand many investigators have found that the ultimate compressive strength of steam cured units is not as great as that of concrete continuously air cured at lower temperature; however, in actual practice concrete is often given very little moist curing so that advantage of steam curing may be considerably greater than would be apparent from comparison with twenty eight-day moist curing.

The steam curing treatment can be modified based on the theory discussed above. Moisture and heat are used in the same way as explained before; however, the way these two elements are applied is slightly different than that of steam curing practice. Instead of steam, vapor is used to accomplish the operation.

As discussed previously newly-made blocks cannot be introduced into a high temperature environment without detrimental effects; consequently, a presteaming period is required in the steam curing cycle to avoid thermal shock which could result in crazing and cracking effects in the blocks.

The vapor curing method achieves the early hardening of the block by following a simpler method. Freshly formed blocks are placed directly (without conventional presteaming period) into the kiln with favorable curing environment of saturated-humidity atmosphere (100% relative humidity) where the temperature is 140°F to 150°F throughout the curing cycle. The blocks do not suffer any detriment. The reason is that the kiln's atmosphere is saturated with vapor, not steam, and each pound of vapor contains approximately 160 BTU's, whereas each pound of steam at 212°F contains approximately 1000 BTU's; thus the temperature rise of the blocks attained in a vapor curing system has a corresponding increase in moisture for hydration, and do not suffer a harmful thermal shock.

High-Pressure Steam Curing System

High-pressure steam curing or autoclaving refers to curing of concrete products in a saturated atmosphere at temperatures above the boiling point of water and in the range of 325°F to 375°F at pressures of about 80 to 170 psig respectively.

Even though high quality block is achieved by this curing method, and totally cured block is obtained in twenty four hours, this practice, which had its boom in the 50's and early 60's, has slowed down lately. It has been substituted in many cases for low-pressure steaming-drying and carbonation curing systems, or simply for low-pressure steam curing system. The main reasons are the high investments involved in the purchase and installation of the equipment, and the high fuel consumption required to drive the system. As mentioned above, cheaper and more economical systems have been developed.

In despite of this fact, high-pressure steam curing systems are briefly discussed below for the sake of completeness in the analysis of the curing operation; however, its analysis is not extended to the equipment available, nor the selection of curing equipment.

Two general methods are used for curing block in high-pressure steam: single-stage curing and two-stage curing. In the former, blocks are moved into the autoclave kilns without first being removed from their pallets, and are cured in one operation. In the two-stage curing, blocks are partially cured (low-pressure steam curing), removed from the pallets, and then introduced into the autoclave in cubes of 90 or more standard units each. Autoclave kilns are cylindrical steel drums, usually six to eight feet in diameter ranging from 50 to over 100 feet in length. They may be open at one or both ends and are fitted with pressure-tight doors.

Both single-stage and two-stage curing methods require to first store the block at ambient temperature for a presteaming period. The reason for this was discussed in the preceding section.

In two-stage curing racks of block are placed in kilns for the duration of the presteaming period. Heat and moisture are then supplied by introducing saturated steam. The blocks are held in the kilns long enough to develop sufficient handling strength so that they may be cubed before being transferred to the autoclave.

In single-stage curing the presteaming period may be accomplished in closed rooms, in kilns with very mild temperatures and high humidities maintained by steam, or in the autoclave itself. The blocks are not removed from the racks or handled individually before going into the autoclave, and so it is not necessary to develop much strength during the presteaming period.

Concrete block plants with autoclaving system involve high degree of automation both in the block handling and materials handling operations.

The two-stage curing system requires a smaller capital expenditure. On the other hand, it has such disadvantages as less effective use of raw materials, darker color of finished blocks, and some staining. However the choice between single-stage and two-stage curing is largely an economic one, since the products from both methods are normally acceptable.

A list of references is provided at the end of this paper.

Equipment Available for Curing

In this section the equipment available for air curing and low-pressure steam curing treatments presented above is discussed briefly to raise the main characteristics of each one.

Air Curing Equipment

Outdoor Air Curing

This method requires the simplest equipment of all and it is composed of a covering and a hose or watering can. This method does not allow frequent reuse of pallets since blocks rest on pallets for at least forty eight hours before they can be cubed, i.e., at least pallets enough for the production of two shifts are required (or 48 hours if more than one shift per day). The block handling equipment includes the pallets required for one shift, thus the extra pallets needed due to air curing should be included also as part of the air curing equipment; this is usually pallets needed for one or one and a half shifts of production.

Indoor Air Curing

The equipment needed for indoor air curing includes extra pallets needed for the period of time before cubing. In this case, extra pallets for four production shifts (or four days if more than one shift per day) are required since the blocks are kept indoors for five days.

The curing room or shed does not require a special design as long as it provides the proper conditions of temperature and humidity. No expensive apparatus is necessary for sprinkling when the blocks are in the shed. A hose or water-can fitted with a rose would be suitable. By a small expense, simple arrangements can be fitted up for sprinkling all the products automatically. One method is to use an ordinary garden sprinkler which can be moved as required so the water reaches the whole. curing area at frequent intervals. Another method is to install a system of overhead pipes with sprays at suitable intervals, placed in such a way that they cover the entire curing area. In order to economize water when the area is not fully occupied, each spray should be fitted with a valve so that any one or more can be cut out when not required.

For considerable large productions this method is hard to practice because a great covered area would be necessary as well as a large amount of pallets and racks. This would increase the capital invested in curing equipment, to the extent that steam curing could be installed for the same amount.

Low-Pressure Steam Curing Equipment

Broadly a steam curing system is composed by the kiln(s), and steam supply equipment.

Kilns

The main factors to be considered in the design of steam curing kilns include (28, 70): 1) production rate of forming machine-block handling equipment setup; 2) number of standard blocks desired per kiln (see comment in page 113); 3) shape, size, and number of kilns; 4) number of units per rack; 5) plant layout; 6) proximity of kilns to forming machine; 7) adequate insulation to assure low heat loss; 8) tight interior surfaces and doors to prevent penetration of moisture into the insulation, or moisture and heat loss to the exterior around the doors; 9) steam supply (steam generator) which insures a saturated atmosphere at a required temperature; 10) distribution of steam for curing; 11) instrumentation for temperature and humidity recording and control; 12) means of exhausting heat and steam after the curing cycle has been completed; and 13) lighting.

The kilns should be located so that loading and unloading are accomplished with a minimum of interference with other plant operations, provide a minimum hazard to plant safety, and have a minimum transport distance for both loading and unloading.

Usually block manufacturers prefer medium sized kiln with a capacity from 1,000 to 2,000 standard blocks per kiln. The reason is the shorter period of time per kiln required for charging. "A good practical standard for the determination of the size of the kiln is that the loading time should not exceed the steaming time, which takes about two or three hours when units of one type only are charge." (28, p. 31)

A concrete block curing kiln normally requires sufficient roof strength to support itself and any load due to snowfall or equipment placed on top of the kiln; sufficient wall strength to support the roof. It should be of the lightest type of construction with the highest degree of insulation. It should be water tight from the inside and outside. The materials used should be corrosion and acid vapor proof.

The kilns should be neither longer, higher, nor wider than needed. There is no advantage in oversized kilns. Figure 4-4 shows a front and side elevation of a typical kiln for steam curing.

Steam Supply

The production of steam can be done with different designs of equipment; all of them should have the ability to provide 100% saturated steam.

The most common practice until some years ago was to use steam boilers in the generation of steam; however, steam generators of higher thermal efficiency, cheaper cost, cheaper installment, safer, and of a lower fuel consumption have been developed and have practically taken over the market.

The reason for the boiler systems to be less efficient is that it has to be placed appart from the kilns and a certain amount of heat is lost as the steam travels through the pipe from the boiler to the kiln. A boiler room has to be built to house the boiler. The boiler itself requires a special design and construction to support a high internal pressure developed during the heating of the water. As a result both initial and operating costs are high.

Some of the most popular steam curing equipment used today in the concrete block production are depicted below.

Boiler System. The first type of equipment discussed is the boiler system; however, the equipment presented is not the conventional boiler. This steam generator has superseded the old fashioned boiler, providing the curing conditions required but performing at a higher efficiency than the conventional boilers.

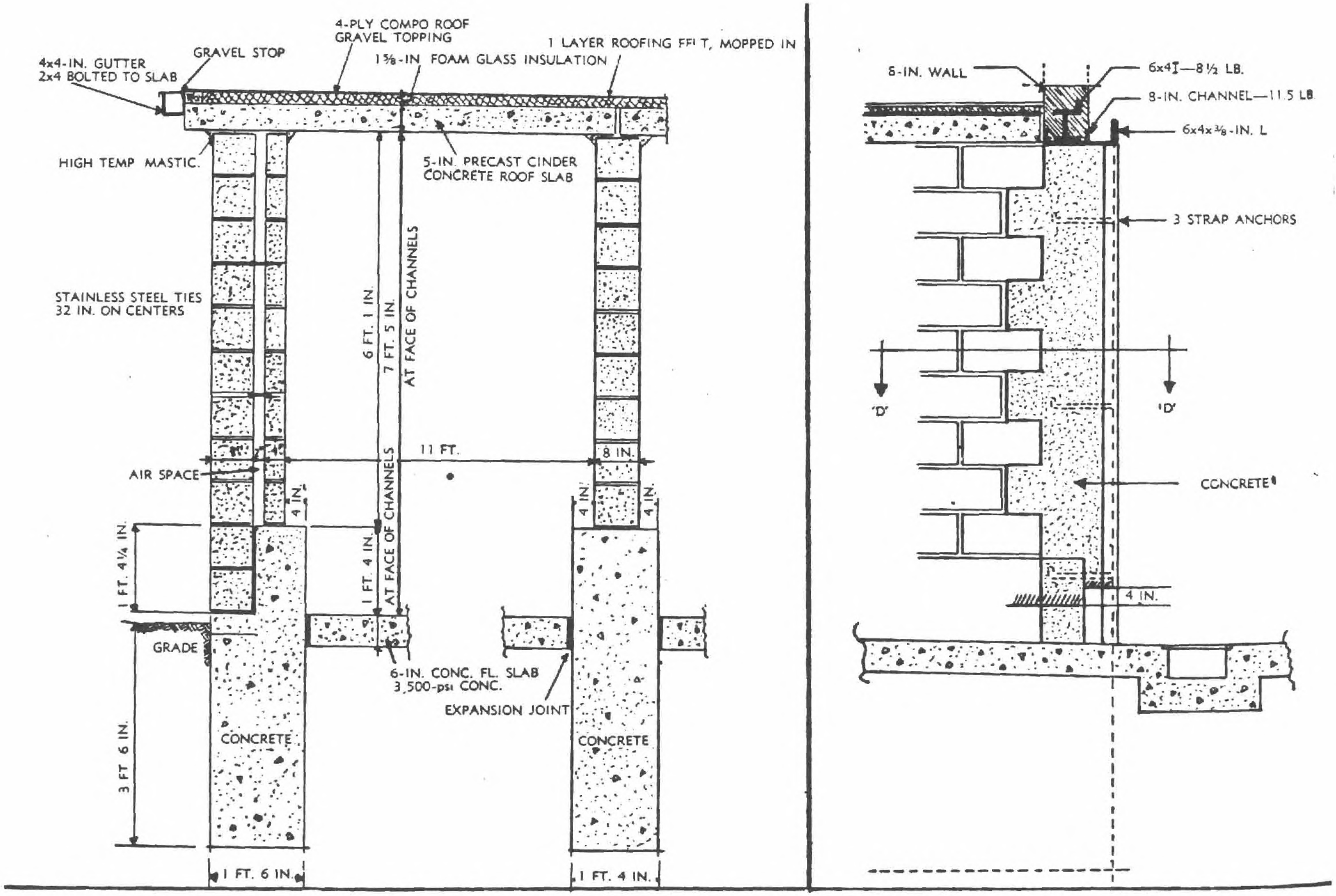


Figure 4-4. Correct Design of a Kiln for Steam Curing.[3]

[3]Grant, W., "Manufacture of Concrete Masonry Units-9," Concrete, July 1951 (pp. 30).

The steam is produced in the generator and conducted through a pipe to the kilns. Each kiln is equipped with a valve and a set of perforated tubes fixed to it sides, floor, and ceiling for the distribution of the steam. The operation can be controlled automatically or manually.

Figure 4-5 shows a steam generator of this kind. In addition to this unit some special valves, a water softener and feed-water test kit, a heated feedwater tank, a gas or oil storage tank, and piping and valve for steaming the kiln are required.

Heat Exchanger Steam Generator. In this case heat and moisture are generated inside the kilns. A heat exchanger liquid heater circulates oil at high temperatures (500°F to 600°F) through a tube network inside the kiln. The tube is immersed in a ditch containing water which is brought to boiling temperatures producing moisture and heat.

Figure 4-6 illustrates this type of equipment.

Direct-Fired Steam Curing System. Other system available for steam curing of blocks burns the fuel directly into a water container inside the kiln.

The burner is located outside the back of the kiln, and fires directly into a vaporizing tank inside the kiln. The steam is produced by the boiling of water in the vaporizing tank. The products of combustion are discharged from the tank directly into the kiln. All the heat generated stays in the kiln in form of steam and products of combustion. Figure 4-7 shows an installation of direct-fired steam curing system.

Each kiln is equipped with its own burner, and work independently from the other kilns. This offers the advantage of being able to make small volume curing jobs without having to activate a large central system

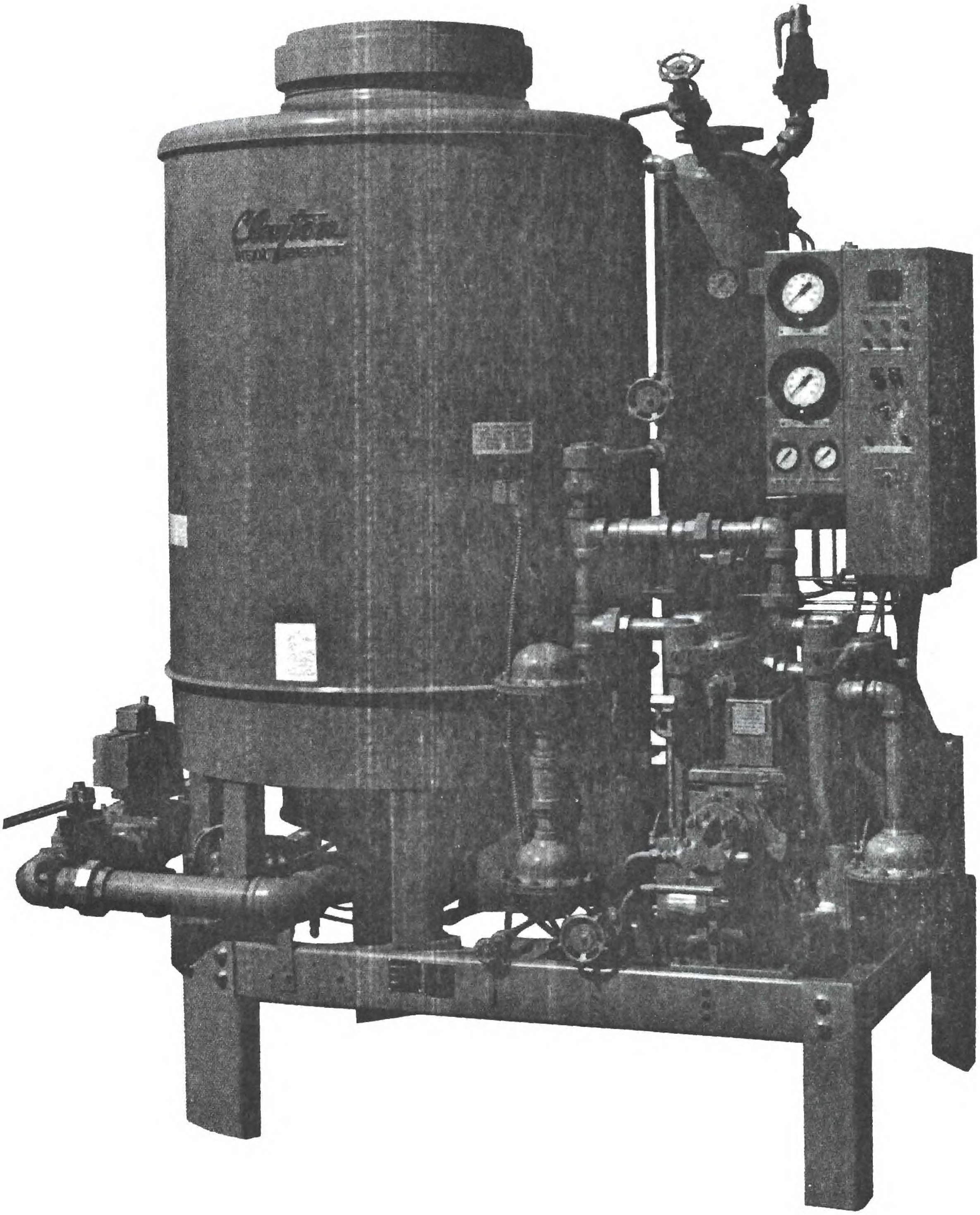


Figure 4-5. Steam Generator

Picture Courtesy of Clayton Steam Generator Co., Atlanta, Ga.

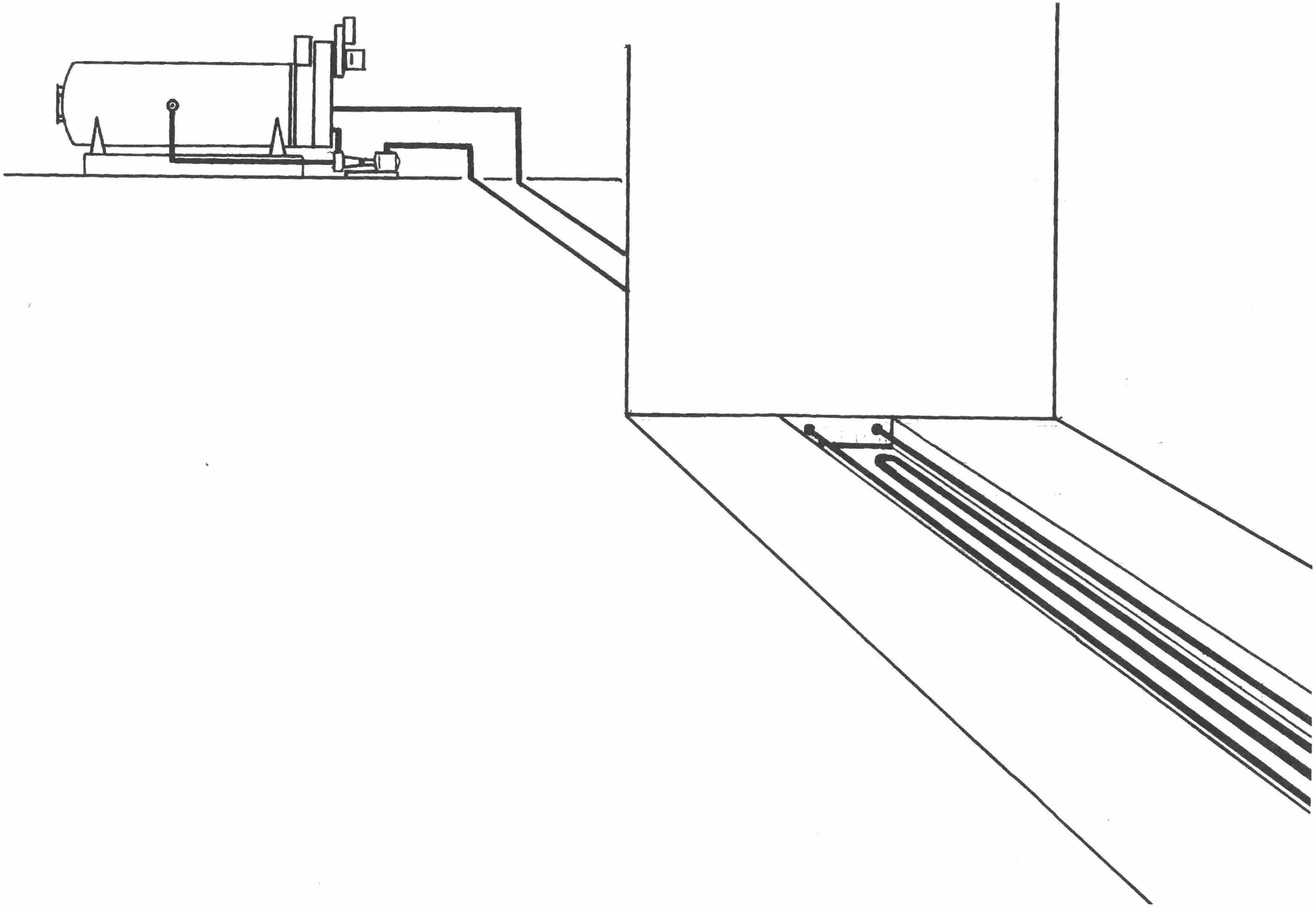
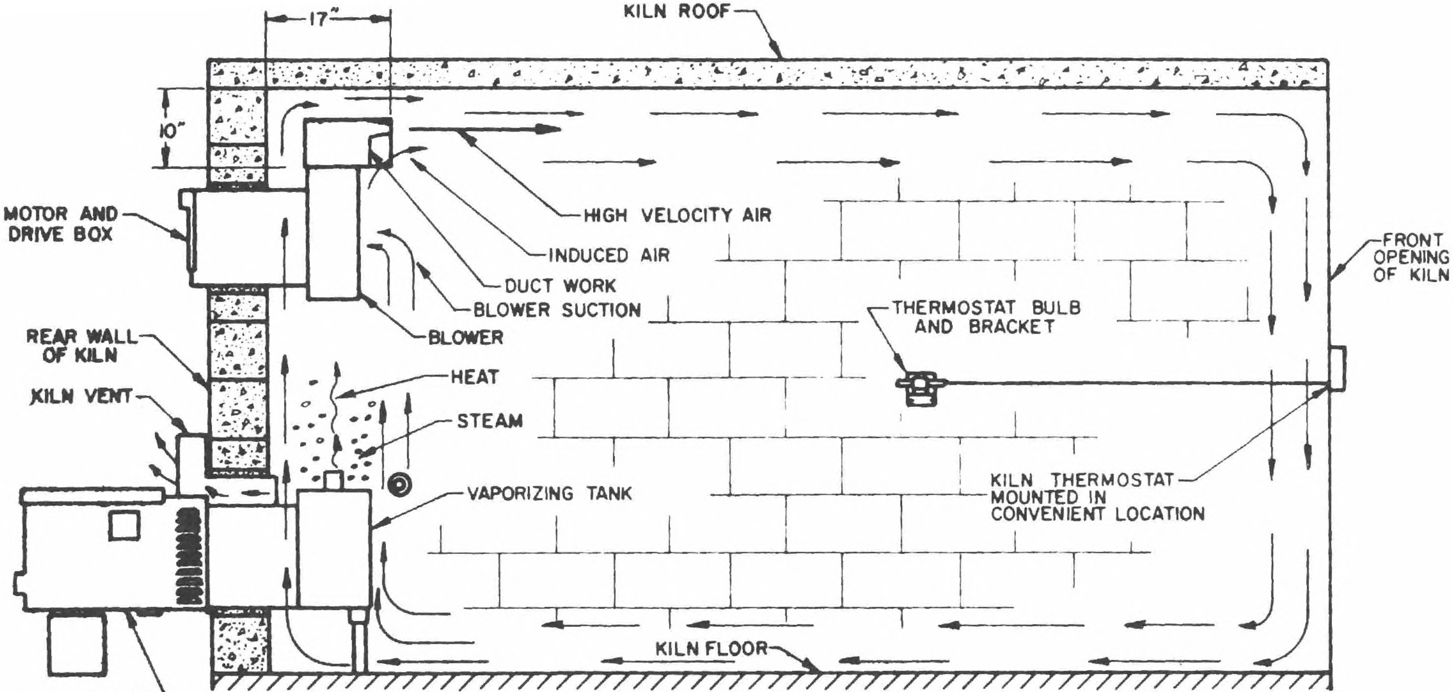


Figure 4-6. Heat Exchanger Liquid Heater Steam Curing System



LONGITUDINAL SECTION THROUGH KILN SHOWING
INSTALLATION AND OPERATION OF JOHNSON KILN AIR CIRCULATOR

Figure 4-7. Direct-Fired Steam Curing System

This drawing was obtained from Johnson Gas Appliance Company; Engineering Bulletin.

when only one or two kilns are being used. In addition, if part of the system happens to break down the rest of it can still work and the curing operation is not totally interrupted.

Direct-Fired Steam Curing and Drying System. Steaming and drying equipment is required for total-curing of blocks, referered as "quick curing" in page 104.

The system includes equipment for 1) conventional direct-fired steam curing, 2) dry and carbonate, and 3) vent. After the steaming cycle has been completed a drying burner is activated along with the kiln air exhauster. The drying burner introduces dry heat and carbon dioxide into the kiln while the kiln air exhauster expels moisture-laden air. This moisture is the result of the steaming cycle, plus what is drawn from the blocks during the drying cycle. Moisture content of the blocks is reduced to the desired level during this cycle, and early compressive strength is established. After the drying cycle is completed the burner stops. The exhauster and circulators continue to operate and any remaining moisture is then expelled from the kiln atmosphere and the blocks and kiln are cooled. At the end of the cycle the blocks are ready for removal from the kiln and delivery.

Figure 4-8 and Figure 4-9 show two layouts of this type of equipment.

Vapor Curing System. The grounds of this treatment were discussed before. Figure 4-10 illustrates the performance of this type of equipment.

Because of the special design of doors the kiln holds a vapor-tight environment and heat losses are cut to a minimum making an efficient system which fuel consumption can be lower than that of conventional curing

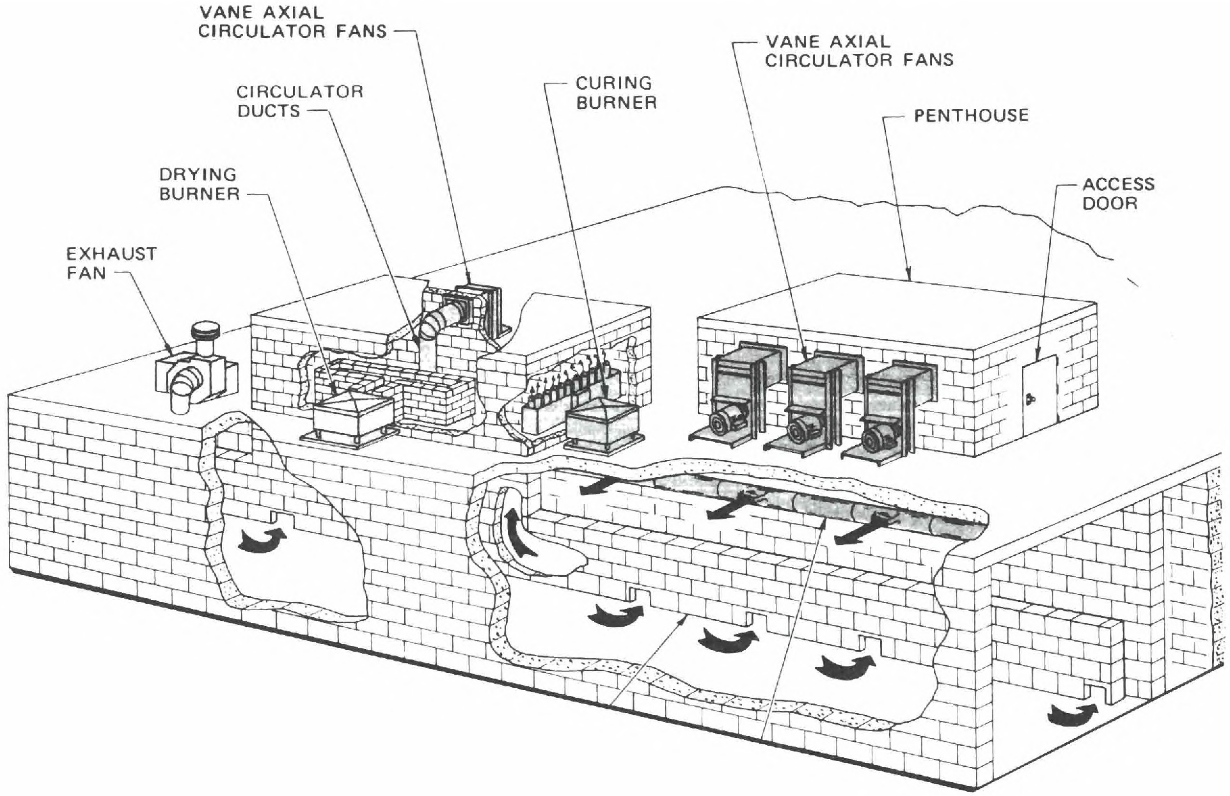


Figure 4-8. Direct-Fired Steam Curing and Drying System (Rooftop Kiln)

Picture Courtesy of Johnson Gas Appliance Company; Engineering Bulletin.

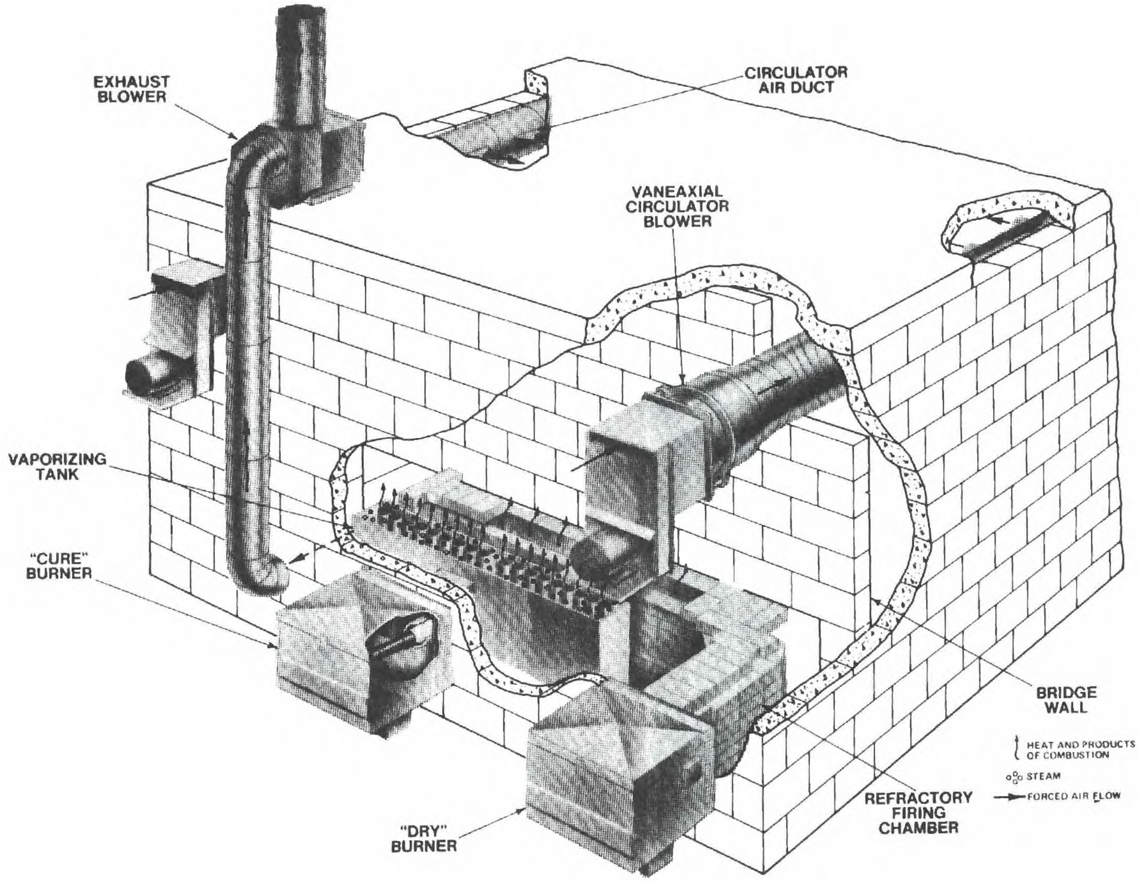


Figure 4-9. Direct-Fired Steam Curing and Drying System (Standard Rear Kiln)

Picture Courtesy of Johnson Gas Appliance Company Engineering Bulletin.

Figure 4-10. Vapor Curing System

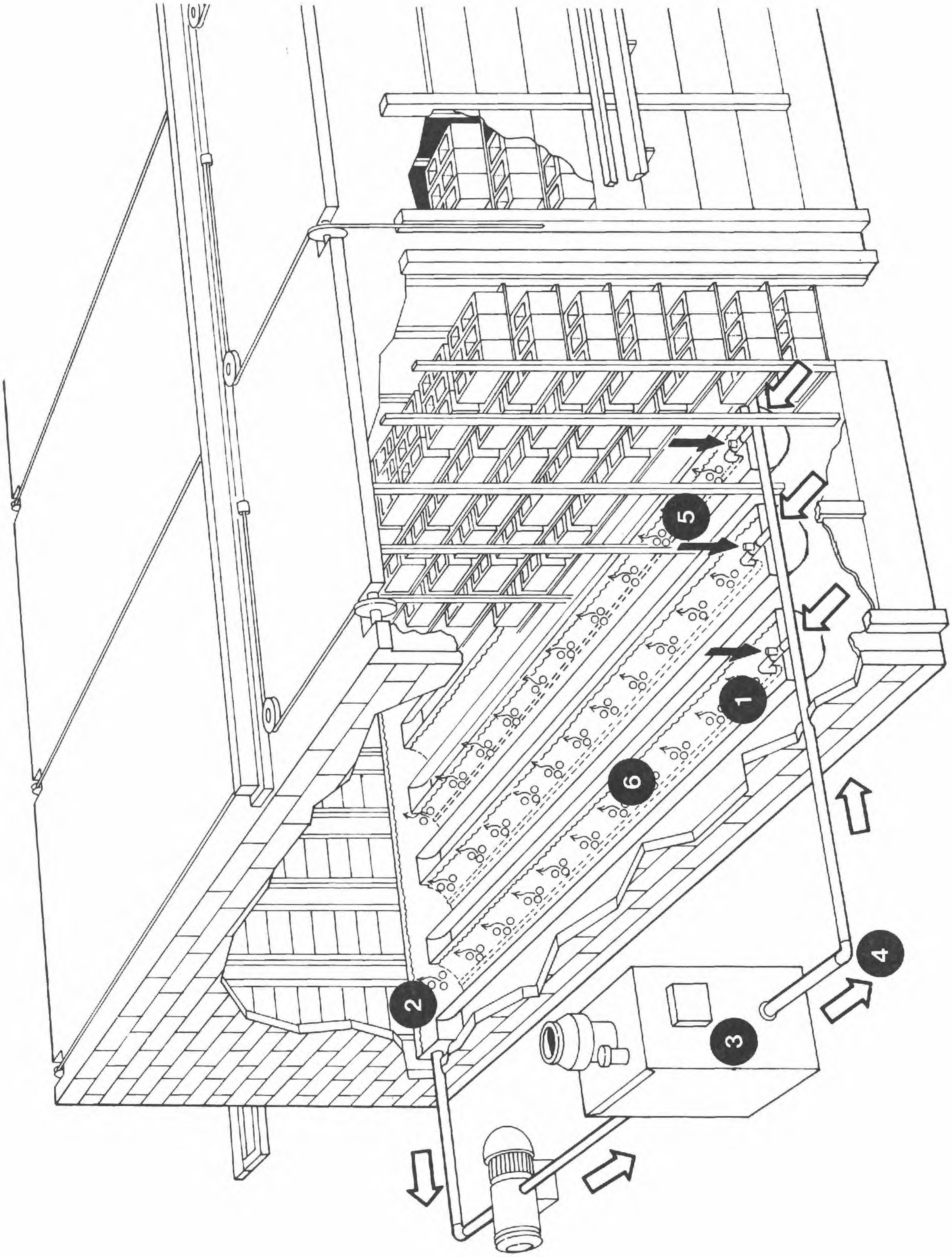
Under each bay of the shelves, there is a pan filled with hot water. 1) Each pan runs the length of the kiln and is attached to the collector pan 2) at the rear of the kiln. Hot water circulates through a hot water heater 3) back to the individual pans. As the newly heated water 4) enters each pan through a venturi, it is aerated by injected kiln air 5) and flows through a long perforated pipe 6) at the bottom of the pan. Bubbling water escapes through the holes in the pipe, rises and sitrubs the surface of the water. This bubbling releases heat and moisture in the form of water vapor (not steam) to the kiln atmosphere for curing. Vapor curing only works in a totally enclosed kiln.

Heat and Moisture

Air into Venturi Tubes

Water Flow

Picture Courtesy of Builders Equipment Company (BECO)


1
2
3
4
5
6

systems. The savings in fuel can be experienced if the system is operated continuously (three eight-hour shifts per day) since the kilns never have to be cooled to retire the blocks and there is no energy wasted to heat it up every cycle. On the other hand, because of this door's design the system can be operated only with fully automatic block handling equipment (see Figure 3-17); whereas, other types of curing systems can be operated either with automatic, semi-automatic, mechanic or even manual block handling equipment.

The five types of equipment discussed above can be operated either manually or automatically and consume either gas or oil (#2).

Selection of Steam Curing System

The overall economy and efficiency of a block plant depends to a great extent upon the care and knowledge used in the original design and construction. The plant should be designed by a competent engineer familiar with plant layout, equipment selection, and curing procedures.

It is not the intention of this paper to provide a guideline for a complete design of a curing facility, but to provide an insight of the equipment available for this operation and present figures of initial investment, labor requirements and energy consumption for the reader to be able to make estimations of cost of capital, operating costs, and plant facilities required for a given plant.

Anyone interested in the installation of a curing facility is advised to contact the manufacturers of this equipment and provide them a complete outline of his particular requirements. This can be prepared based on the size and elements of a system. The size of the system should be based on heat requirement calculations which include production schedule, curing cycle, and present and future plant needs. Calculations should include required heat to raise the temperature of the block; steel racks and pallets; air inside the kiln; roof, floor, and walls of the kiln; and to compensate for heat loses to the outside during the heating and soaking periods (30). In addition, type of climate of the regions, including brackets of temperatures for each season of the year are helpful.

Table 4-2 presents estimations of cost of initial cost of low-pressure steam curing equipment. The figures were obtained based on information from manufacturers and are estimates of the average cost of equipment of each size and type. Since air curing equipment does not involve machinery, standard sizes of equipment are not available; as a result, figures of air curing systems are not estimated, instead Chapter IV Appensix IX discusses how the cost of air curing equipment can be estimated.

The cost of kilns is not included in this table because it varies greatly from one region to another due to differences in cost of materials for construction and cost of labor. Based on the discussion of "kilns" presented before, cost of kilns should be estimated for particular requirements and construction costs.

For large production outputs (5,000 to 9,000 units) cured outdoors or indoors one man is required full time to attend the treatment, watering and covering the blocks as necessary; smaller productions can be handled by a man devoted to this and some other task at the same time.

In the case of low-pressure steam curing with manual controls, one man is needed to control the operation. If the operation is controlled automatically, the system only has to be activated at the beginning of the cycle. For practical purposes no labor is required since the

Table 4-2. Estimation of Initial Cost of Low-Pressure Curing Systems Equipment (U.S. Dollars)

Curing Capacity	Low-Pressure Steam Curing				
	Boiler System	Heat Exchanger	Direct-Fired	Direct-Fired (Total Curing)	Vapor Curing System
500-1000	------	------	2,500	------	------
2-3000	15,000	13,000	6,000	17,000	15,000
4-6000	20,000	17,000	10,000	25,000	22,000
7-9000	25,000	20,000	13,000	38,000	30,000
10-14000	31,000	25,000	20,000	55,000	35,000
15-17000	36,000	30,000	25,000	65,000	40,000
18-23000	45,000	38,000	30,000	85,000	50,000

Calculations based on the upper number of the bracket.

These figures are for manually operated equipment. The automatic controls raise the price in 25% approximately.

foreman usually can cover this task.

Air curing systems do not use fuel, but need a considerable amount of water since much of the water sprinkled is wasted. It is hard to pinpoint an average quantity of water used per block, but for practical purposes it has been assumed to be half a gallon of water per block per day. The water consumption of low-pressure steam curing equipment is shown in Table 4-3.

Table 4-4 contains the electric power requirements of the low-pressure steam curing systems under analysis. As mentioned previously, the equipment can be used with gas or oil as fuel. Table 4-5 presents the rate of fuel consumption both for gas and oil for the equipment under consideration.

Table 4-3. Water Consumption in Gallons/Hr.

Curing Capacity of Equipment	Low-Pressure Steam Curing Equipment				
	Boiler System	Heat Exchanger	Direct-Fired	Direct-Fired (Total Curing)	Vapor Curing System
500- 1000	---	---	30	30	---
2- 3000	175	118	60	60	89
4- 6000	318	219	120	120	169
7- 9000	530	355	180	180	268
10-14000	795	538	270	270	404
15-17000	1060	648	330	330	489
18-23000	1590	1005	420	420	713

Table 4-4. Horsepower Installed

Output Capacity of Equipment	Low-Pressure Steam Curing				
	460 V 60 Hz	460 V 60 Hz	120 V 60 Hz	120 V 60 Hz	460 V 60 Hz
500- 1000	----	----	1.33	-----	----
2- 3000	2.0	2.0	4.00	6.80	5.4
4- 6000	5.0	5.0	5.33	9.00	7.2
7- 9000	7.5	7.5	7.33	12.40	10.0
10-14000	10.0	10.0	12.00	20.30	16.5
15-17000	15.0	15.0	15.00	25.40	20.0
18-23000	25.0	25.0	25.00	42.32	34.0

Table 4-5. Rates of Fuel Consumption for Steam Curing Equipment

Type of Fuel	Low-Pressure Steam Curing Equipment				
	Boiler System	Heat Exchanger	Direct-Fired	Direct-Fired (Total Curing)	Vapor Curing System
Natural Gas (Cu. Ft. per Hr. per Block)	1.000	0.666	.666	2.000	.333
Oil #2 Gal./Hr./Block	0.0084	0.0066	0.0066	0.0166	0.0028

CHAPTER V

TECHNOLOGICAL ALTERNATIVE FOR MATERIAL HANDLING AND MAKING THE CONCRETE

This Chapter follows the same format as Chapter III. In the first part the characteristics of each type of available equipment are discussed; and, as in preceding chapters, classified under levels of technology and capacity. The second part of the chapter deals with the development of costs, labor requirements, and energy for each of the levels of technology and capacity.

Although material handling is the first step in concrete block production, its analysis was postponed because capacity requirements for material handling equipment depend on the output capacity of the forming machine and block handling equipment, and putting it off simplified the analysis.

Stage I. Material Handling and Concrete Making

Part 1. Equipment Available

This part deals with the description of the equipment available for material handling and concrete making stage of the block production process.

Stage I is composed of six operations as shown in Figure 2-2 and listed on page 12. The raw materials-aggregates, cement, and water are handled separately until they are mixed to make the concrete.

Based on the sequence of the operations in this stage and information collected from equipment manufacturers and concrete block producers, material handling and concrete making technology alternatives were classified under levels of technology:

I) Automatic/bins-silos for in-process storage/automatic backup storage system.

II) Automatic or semi-automatic/bins-silos for in-process storage.

III) Mechanized/front- loader/aggregates stored on the ground, and cement in a silo.

IV) Mechanized/front-loader/aggregates stored on the ground, and cement handled in sacks.

V) Semi-mechanized/front-loader/aggregates stored on the ground, and cement handled in sacks.

VI) Manual/barrows/aggregates stored on the ground and cement handled in sacks.

The results of this classification are presented in Table 5-1. The first column represents the levels of technology or types of equipment available to carry out the material handling and concrete making activity. The second column presents the variants or different alternative sets of equipment within each level of technology. Columns three to eight, labeled with each operation name and number, show the operations of the material handling and concrete making activity.

Since aggregates and cement are handled separately until they are mixed (Operation 5) each column has two internal columns, one for each material. It is assumed that piped water is available and water can be deposited directly into the mixer. Thus only column six has a column for water. The terms in the body of the table typify the equipment available for each operation.

Table 5-1. Type of Equipment Used for the Material Handling and Making The Concrete

Level of Tech.	Set	OPERATIONS: Storage 1		Convey Matls. to Batching 2		Batching 3			Batch to Mixer 4		Mixer 5	Convey to Machine 6
		Aggregates	Cement	Aggregates	Cement	Aggregates	Cement	Water	Aggregates	Cement	Mixing	Mixing
I	I-1	Bins	Bin/ Silo	Auto.	Auto.	Auto.	Auto.	Auto.	Auto.	Auto.	Auto.	Auto.
II	II-1	Bins	Bin/ Silo	Auto.	Auto.	Auto.	Auto.	Auto.	Auto.	Auto.	Auto.	Auto.
	II-2	Bins	Bin/ Silo	Semi-Auto.	Semi-Auto.	Semi-Auto.	Semi-Auto.	Auto.	Semi-Auto.	Semi-Auto.	Semi-Auto.	Semi-Auto.
III	III-1	Ground	Silo	Front-Loader	Semi-Auto.	Manual Control (weight)	Manual Control (weight)	Auto.	Manual Control	Manual Control	Semi-Auto.	Semi-Auto.
	III-2	Ground	Silo	Front-Loader	Semi-Auto.	Manual Control (volume)	Manual Control (volume)	Auto.	Manual Control	Manual Control	Semi-Auto.	Semi-Auto.
IV	IV-1	Ground	------	Front Loader	------	Manual	Sacks	Manual Control	---------	-------	Semi-Auto.	Semi-Auto.
V	V-1	Ground	------	Barrow	------	Manual	Sacks	Manual Control	---------	-------	Semi-Auto.	Semi-Auto.
VI	VI-1	Ground	------	Barrow	------	Manual	Sacks	Manual	---------	-------	Manual Mixer	Manual Hoist
	VI-2	Ground	------	Barrow	------	Manual	Sacks	Manual	---------	-------	Shovel	Barrow-Hoist

It is important to mention that Table 5-1 does not mean that equipment classified under Level I has to be set with block handling equipment of Level A. As mentioned above, the reader will be able to pick a material handling equipment based on the block production desired.

The two main operations in the material handling and concrete making activity are batching and mixing. The rest is pure material handling. The materials (aggregates and cement) are brought from suppliers and stored. For aggregates the storage can be of two kinds: bins or simply piles on the ground. The aggregate bins can be designed to be close to the ground (or on the ground), or at a higher level that the rest of the plant. These two alternatives result in two different layouts of material handling systems: low profile and high profile plants. The cement storage can also be of two kinds: cement silo for handling of bulk cement, or simply a warehouse to store cement delivered in sacks. Cement silos are usually used for handling large amounts of cement since it facilitates greatly the task. However, if the production is not large, sacks can be handled easily. In some regions only sacked cement is available.

In order to facilitate the presentation, the first discussion will deal only with material handling and concrete making equipment for use where aggregates are stored in bins and cement in silos (Technology Levels I and II). Later on, the discussion will deal with equipment for use when aggregates are stored on the ground and silos still kept for cement handling (Technology Level III). Finally, one more step is given towards manual equipment analyzing a situation where aggregates are stored on the ground, and cement is handled by sacks (Technology Levels IV, V, and VI).

Materials Handling and Concrete Making

Levels of Technology I and II

Since the equipment classified under technology Levels I and II is very similar, in order to set a background and facilitate the analysis, their discussion is presented together.

As mentioned before at Levels I and II aggregates are stored in bins and cement in silos. The discussions of low profile and high profile plants are made separately.

Low Profile Material Handling and Concrete Making System. Low profile systems have two types of layout. The aggregates bins can be on the ground or close to the ground. The former case is shown in Figure 5-1. The delivery truck dumps the aggregates into the aggregate ground storage hoppers (Operation 1). When a batch of concrete is prepared the materials are conveyed to the batcher (Operation 2) by means of a belt conveyor.

The cement is stored in a silo (Operation 1) which is equipped with a pneumatic pump or a bucket type conveyor to transfer the material from the delivery unit (truck or train wagons) to the silo. For proportioning, the cement is conveyed to the batcher by means of a screw conveyor (Operation 2).

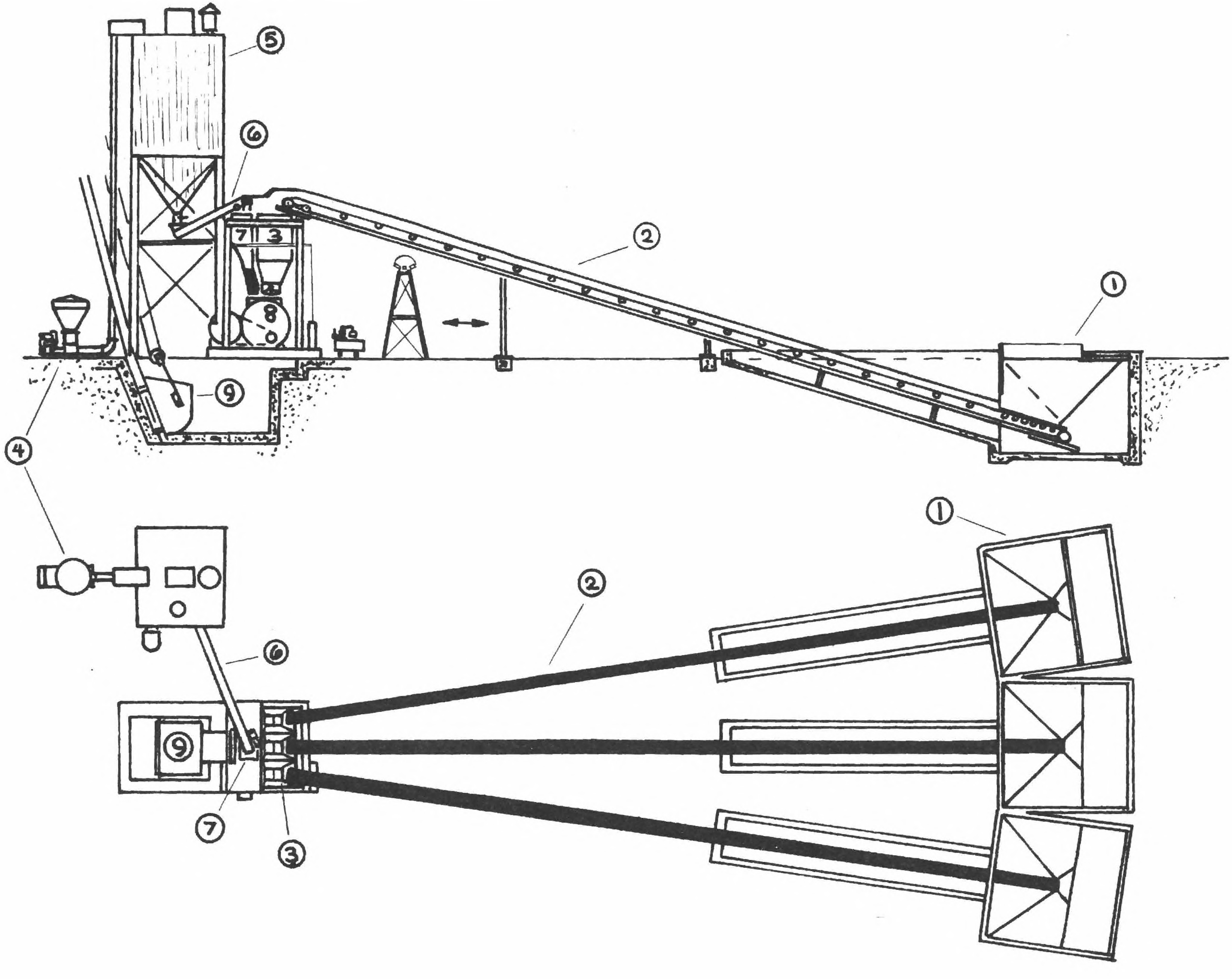
Figure 5-2 shows a layout where the aggregate bins are above the ground level but still at a low profile level.

When equipment like the one shown in Figures 5-1 and 5-2 is available, usually the batching of materials (Operation 3) is made by weight. An aggregate-cement combination batcher, or an aggregate and cement batchers can be used.

Figure 5-1. Low Profile Material Handling System

1. Ground Storage Hoppers
2. Belt Conveyor
3. Three Compartment Aggregate Weight Batcher (Beam Scale)
4. Pneumatic Pump
5. Cement Silo
6. Screw Conveyor
7. Cement Weight Batcher (Beam Scale)
8. Mixer
9. Skip Hoist

Picture Courtesy of Besser Co.

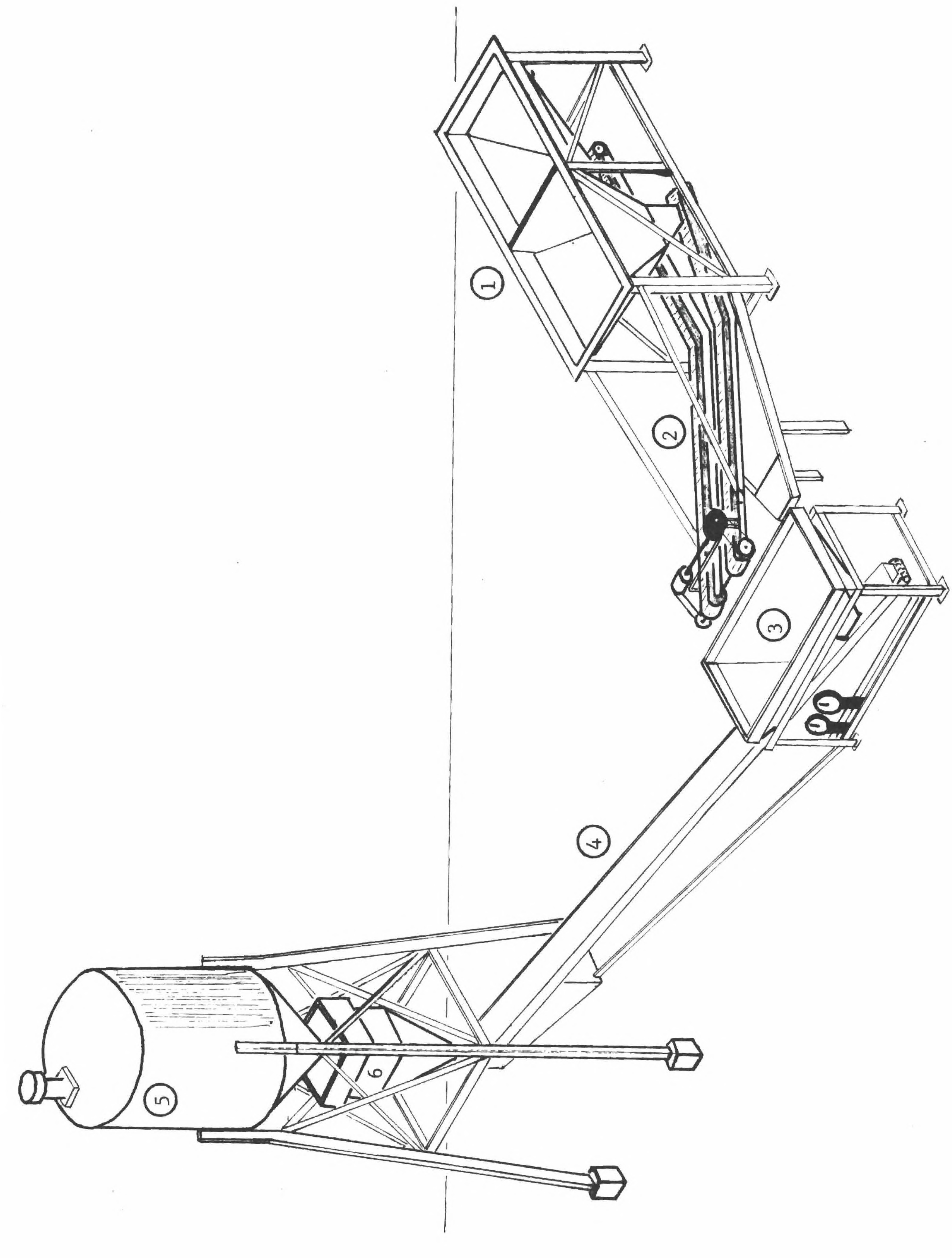


5
6
7
3
8
2
1
9
4

Figure 5-2. Low Profile Material Handling System

1. Two Compartment Aggregate Hopper
2. Belt Conveyor
3. Aggregate Weight Batcher (Dial Scale)
4. Belt Conveyor leading Batch of Aggregate to Mixing
5. Cement Silo
6. Cement Weight Batcher

Design Obtained from MERTS Manufacturing & Engineering Co.


1
2
3
4
5
6

Both batchers can be equipped with either beam or dial type scales. The beam type is simpler, cheaper, and easier to maintain. However, the dial scales have taken over the market because they adapt better to sophisticated control equipment. Another advantage of the dial scales is that it gives a continuous reading of how much weight is in the batcher at any given time. The indicator of the beam scale only shows the operator if the batcher is empty or full.

As the Figure 5-1 indicates, in low profile material handling system of this type, batchers are just above the mixer. Consequently when the batches are ready they are dumped (Operation 4) into the mixer following the proper order. (23, 24, 25, 27, 34)

In other designs of ground storage hopper the aggregate batcher is installed just below the hopper, which by means of a clampshell gate allows the materials to flow into the batcher. In turn, the batches are conveyed by a belt conveyor to the mixer. The cement batcher can be placed under the silo and then the screw conveyor transfers the proportions of cement to the mixer. A layout of this type is shown in Figure 5-3.

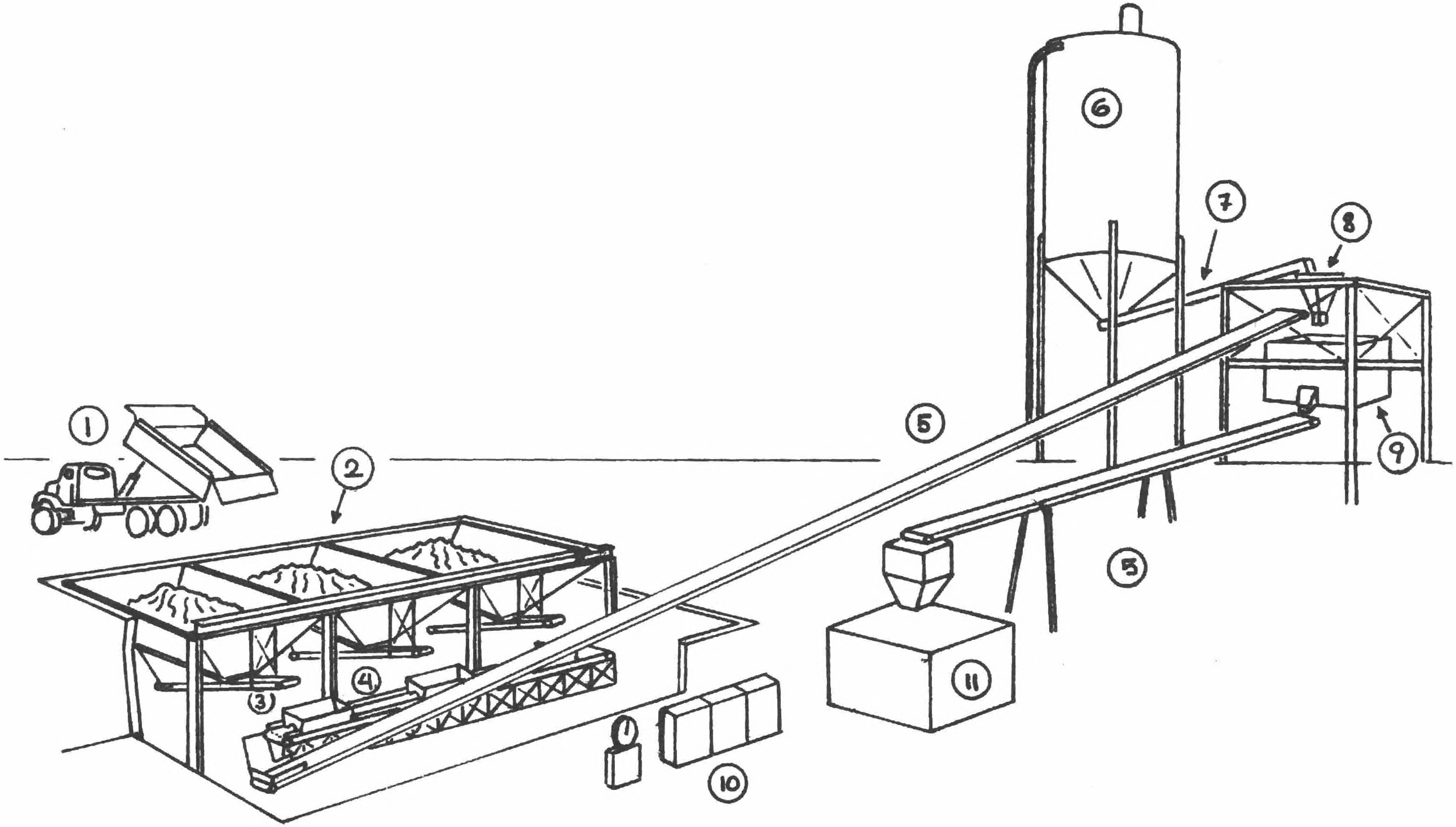
Water in all cases (Figures 5-1, 5-2, and 5-3) is measured in the mixer with a probe. The probe measures the electrical resistance of the mix as water is introduced. A predetermined resistance will cause the water valve to shut. Most mixers come equipped with this feature or it can be easily installed.

The mixing cycle (Operation 5) includes changing the mixer, mixing, and discharging the mixer, and takes between seven to ten minutes. The mix is conveyed to the forming machine by means of a skip-

Figure 5-3. Low Profile Materials Handling System

1. Delivery Truck
2. Aggregate Bins on the Ground (Three Compartments)
3. Feeder Conveyor, give close and accurate discharge of Aggregates into Weighing System.
4. Weight Belt is suspended under the Feeders and has Dial Scale with Lever Arms.
5. Incline Conveyors transfer Materials from Batcher to the Mixer; then from the Mixer to the Forming Machine.
6. Cement Silo
7. Screw Conveyor
8. Cement Weight Batcher
9. Mixer
10. System's Controls
11. Forming Machine

Design Obtained from Standley Bin and Conveyor Co.


1
2
3
4
5
6
7
8
9
5
10
11

hoist, or a belt conveyor as shown in Figures 5-1 and 5-3 respectively.

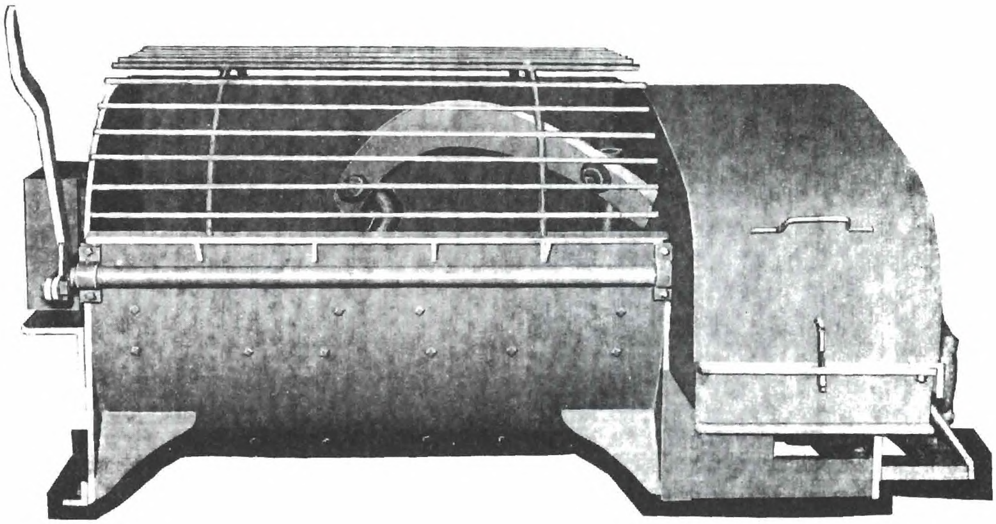
There are many kinds of mixers and a wide variety of sizes. In the block industry the sizes normally go from 125 cu. ft. (120 horsepower) to 16 cu. ft. (10 horsepower). Rates of production of 23,000 and 1,000 standard block/shift can be served respectively. Figures 5-4, 5-5, 5-6, and 5-7 show some examples of mixers.

High Profile Material Handling and Concrete Making System. The high profile system is somewhat different regarding the handling of aggregates. However, batching and mixing are accomplished in the same way as in the low profile system.

As presented in Figure 5-8, the aggregate bins stand at higher levels than the rest of the plant. Often overhead bins have a special compartment for cement as is the case of this figure. Nontheless, a silo can be used just as in the system described above.

Aggregates coming from suppliers are dumped into a truck hopper and conveyed to the bins (Operation 1) by means of a belt conveyor. The cement is transfered to the cement compartment on the bin (Operation 1) by a bucket type conveyor. This is done with a pneumatic pump, as mentioned, if silos are used.

The main characteristic of the high profile systems is that the batcher is supported right underneath the bins, and the mixer stands below the batchers in the same vertical line. As a result, Operations 2 and 4 are simplified transfering the materials by gravity from bins to batchers and batchers to mixers respectively. The mixer discharges the mixture onto a skip hoist as shown in Figure 5-9. Sometimes the mixer stands high enough to allow room to set the forming machine right under-



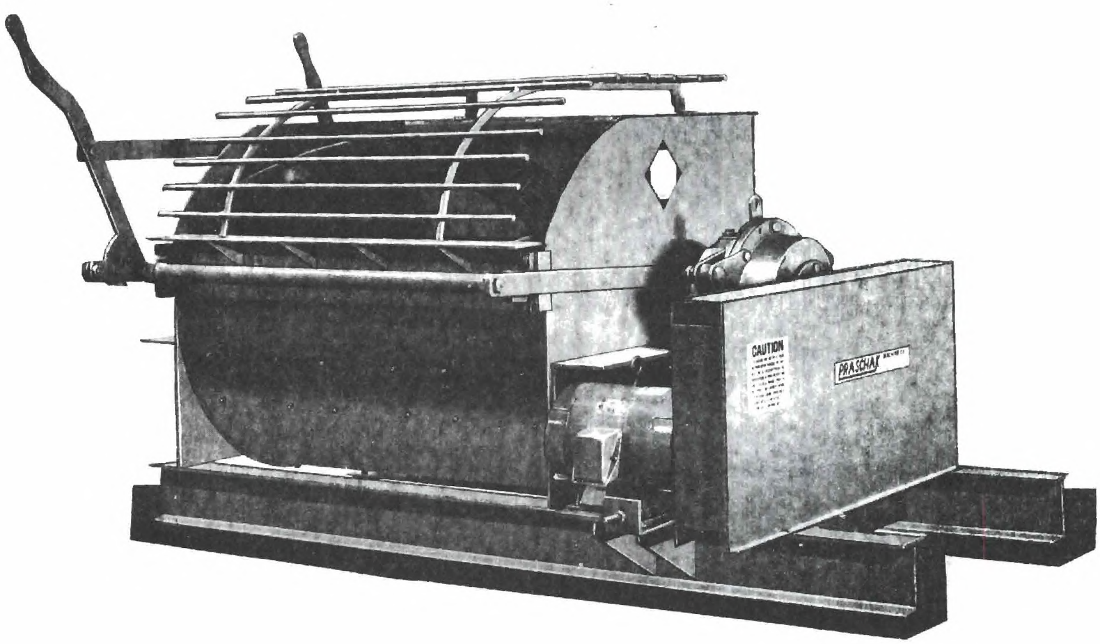


Figure 5-4. Slump Batch Mixers

Open Gear (Above), Direct Drive (Below)
16 Cu. Ft. and 21 Cu. Ft. Capacity
10 Horse Power Motor

Picture Courtesy of Praschak Machine Co.

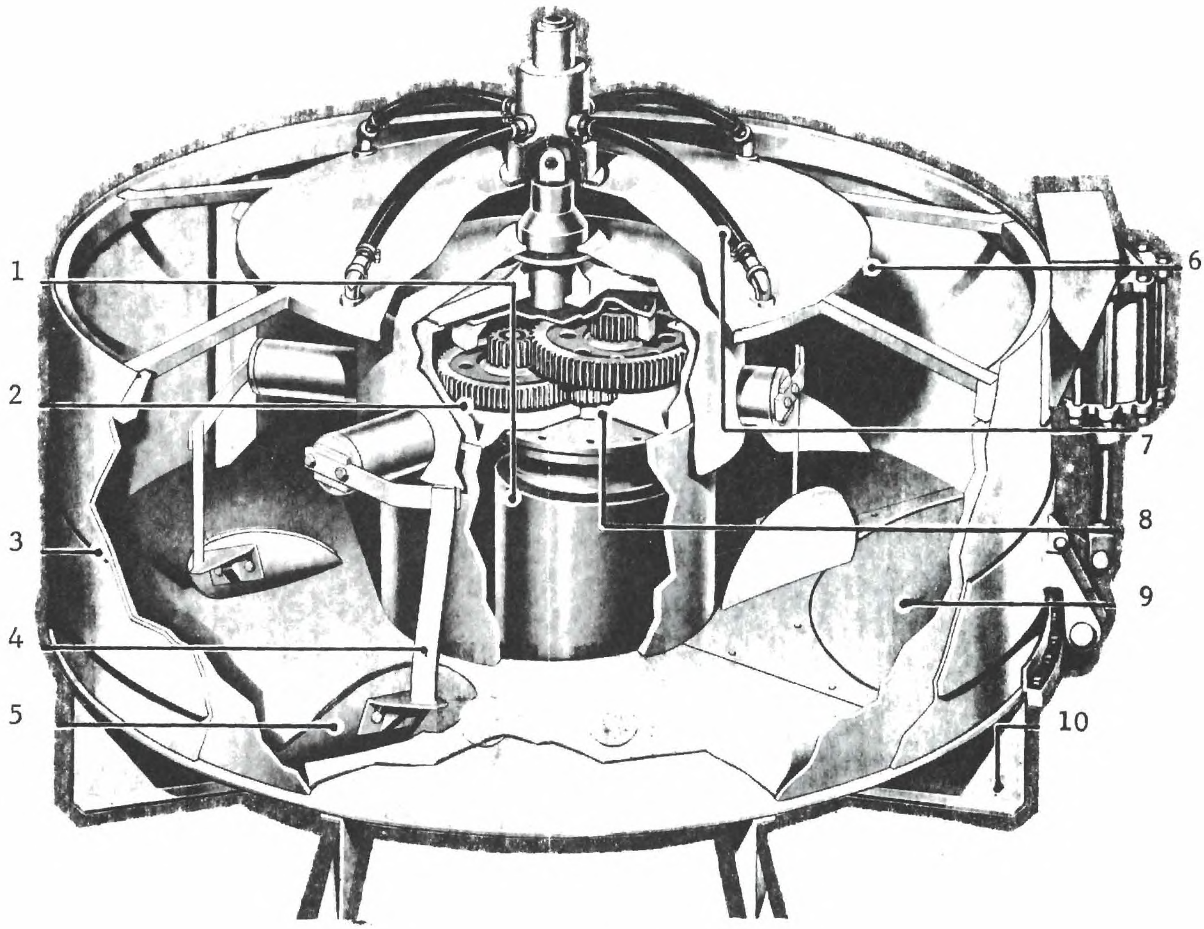
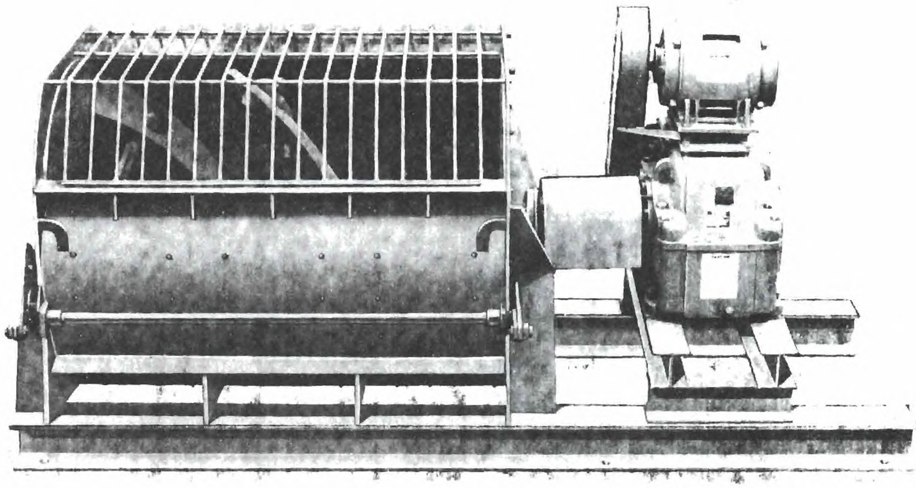


Figure 5-5. Turbine Type Mixer

Low charging height. The opening is right on top and can be charged at any point on its circumference.

1. Motor 230 or 460 Volt, 3 Phase, 60 Cycle, Vertical Mount, directly coupled to Transmission.
2. Transmission
3. Liners
4. Arms
5. Paddles
6. Dust Cover
7. Water Distribution System; provides fast, uniform distribution of water supply.
8. Shaft
9. Door; drop or slide opening door.
10. Supports

Picture Courtesy of Smith Co.



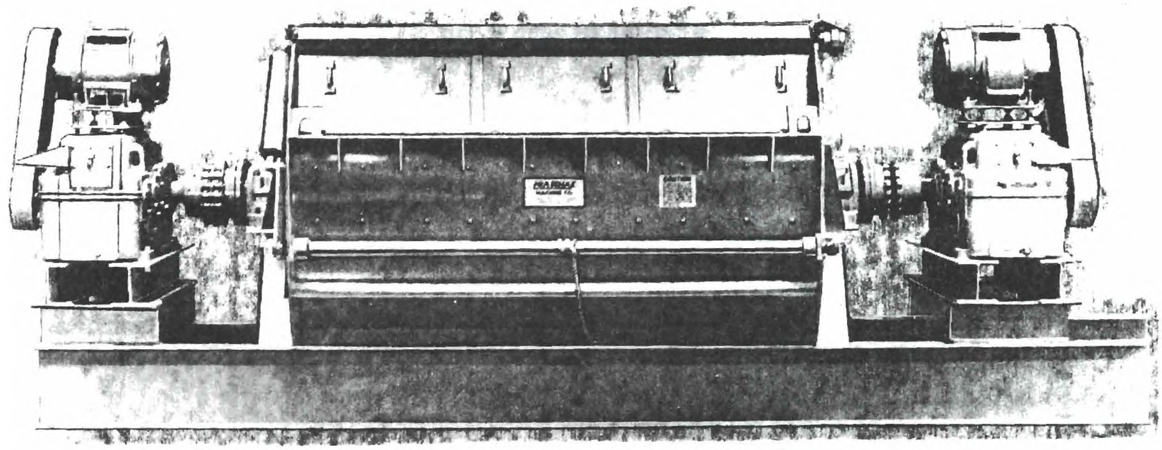


Figure 5-6. Direct Drive Batch Mixers

3 Cu. Yd., 75 H.P. Motor (Above)
4 Cu. Yd., two 60 H.P. Motor (Below)

Picture Courtesy of Praschak Machine Co.

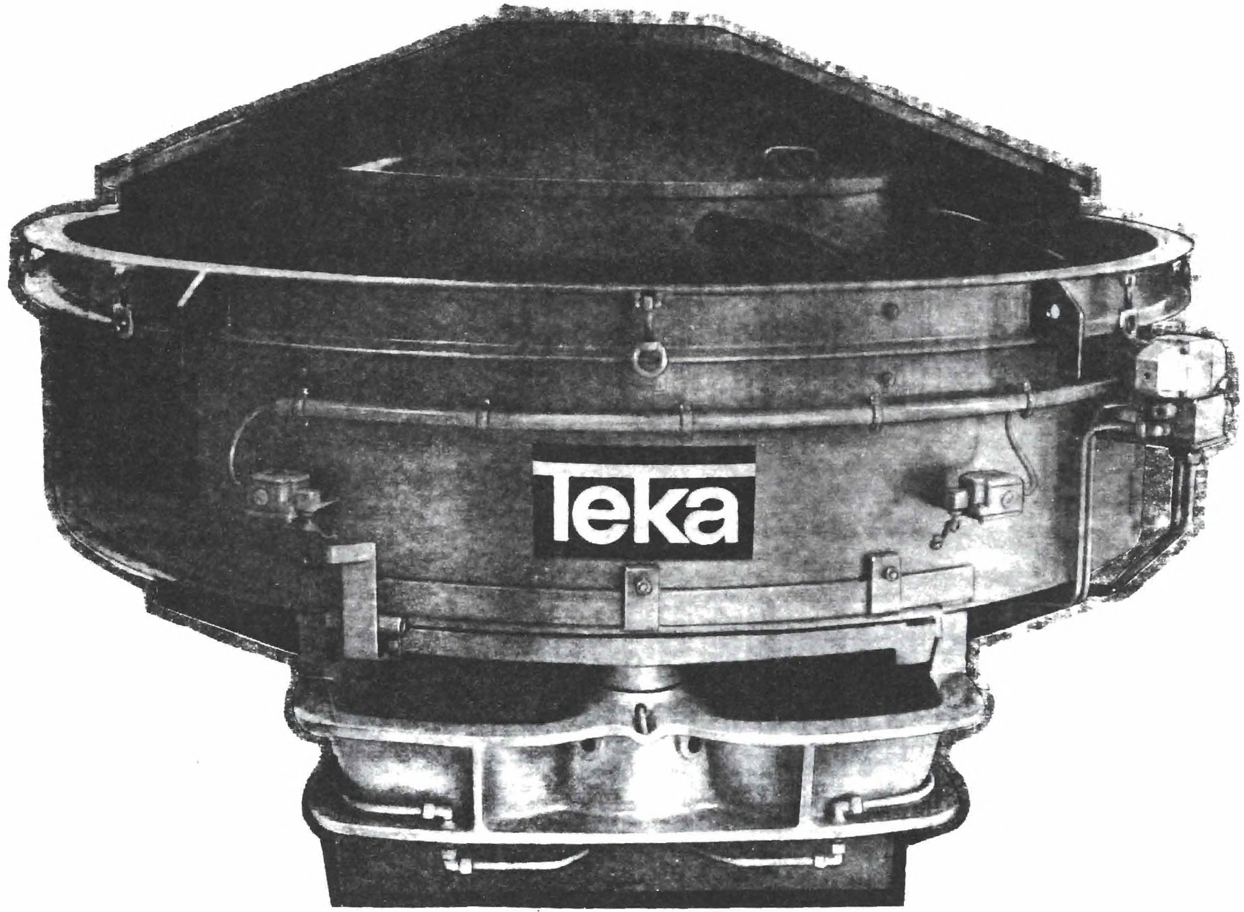


Figure 5-7. Turbine Type Mixer

Picture Courtesy of Teka Equipment Corp.

Figure 5-8. High Profile Material Handling System

1. Delivery Truck
2. Truck Hopper
3. Belt Conveyor
4. Distributor of Materials
5. Four Compartment Bin (Three Aggregates, One Cement)
6. Aggregate Weight Batcher (Beam Scale)
7. Cement Weight Batcher (Beam Scale)
8. Mixer
9. Space for Skip Hoist

Design Obtained from Besser Co.

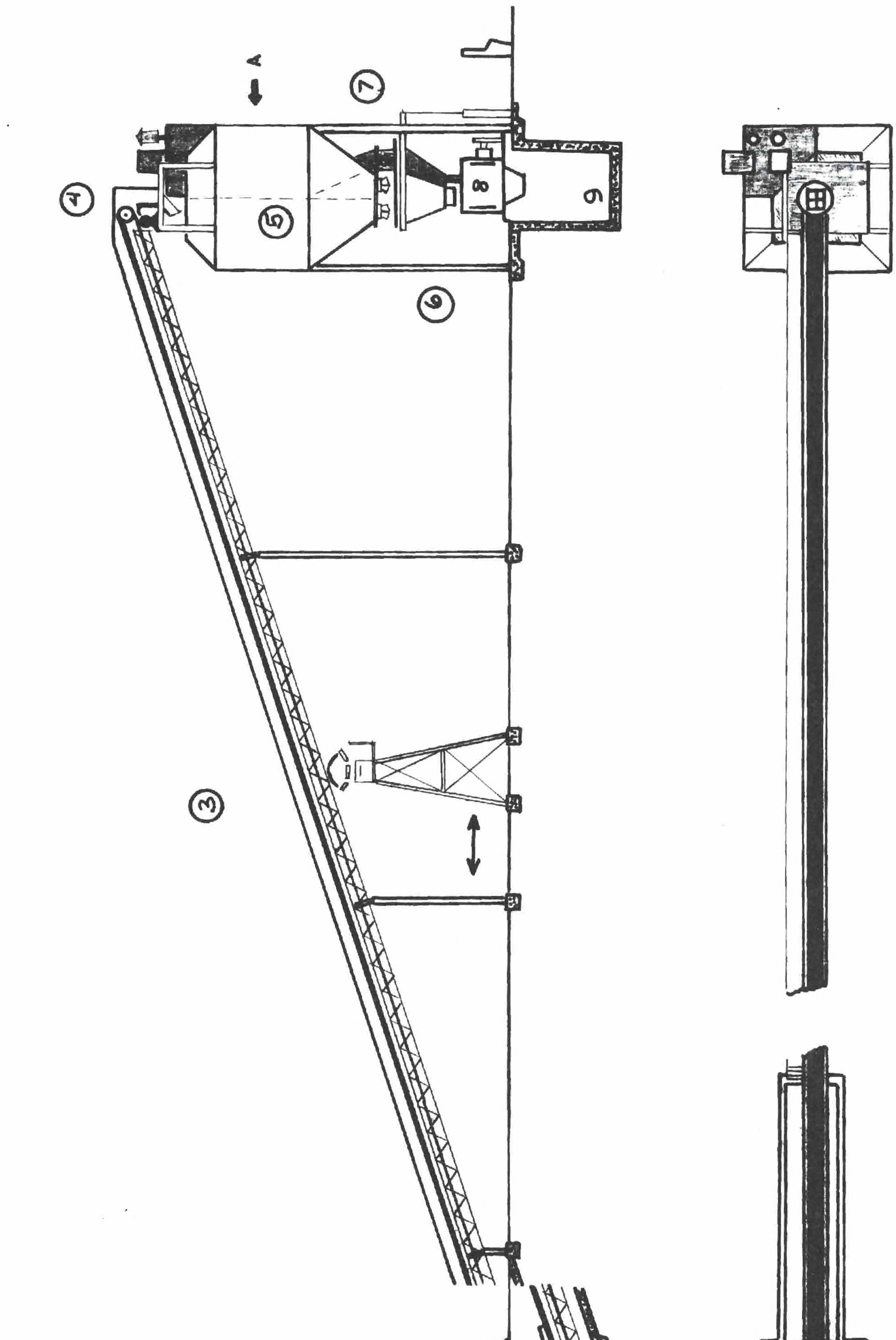
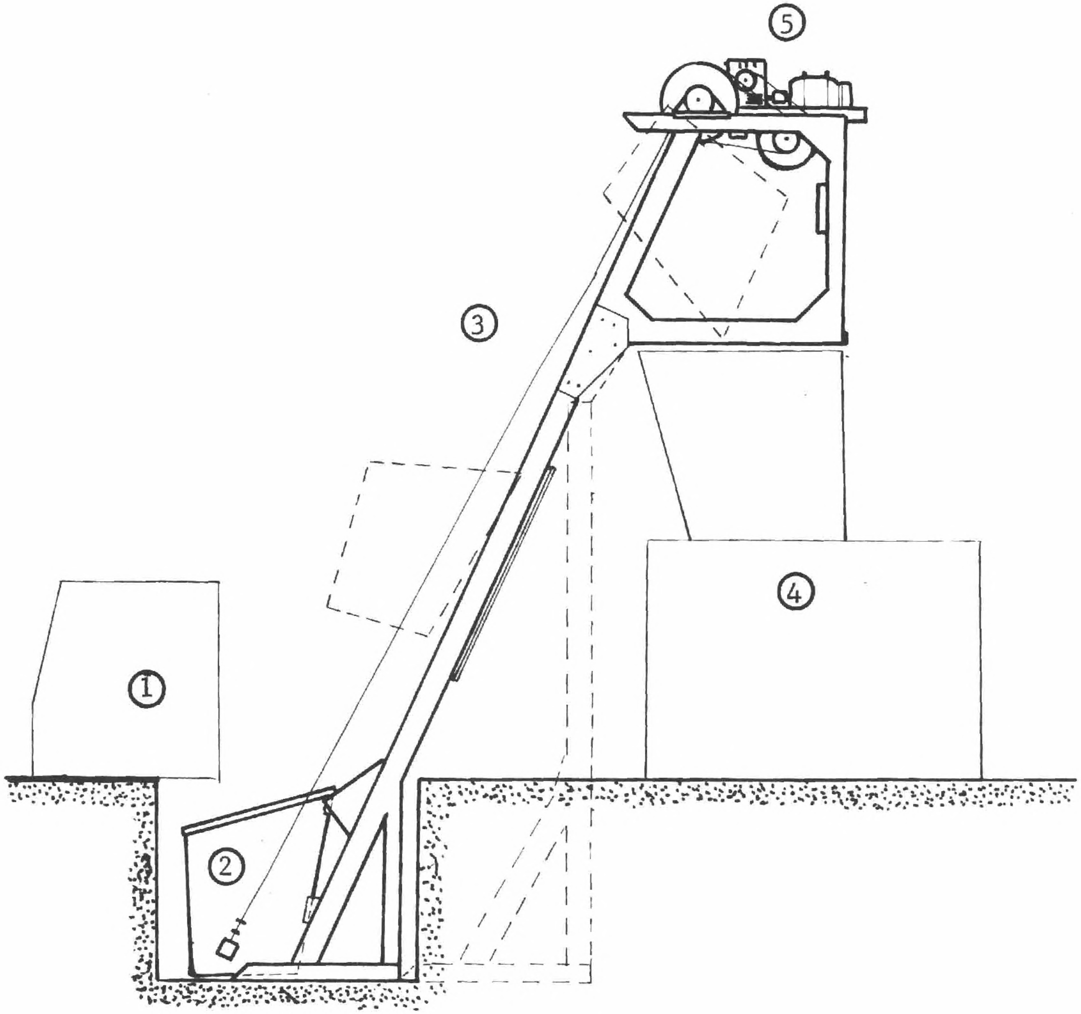

1
2
3
4
5
6
7
8
9
A

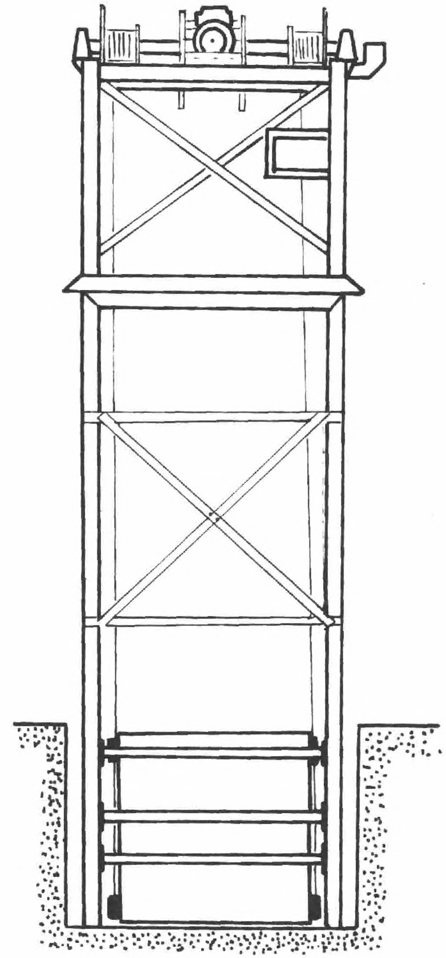
Figure 5-9. Skip Hoist

1. Mixer
2. Skip Hoist
3. Hoist Cables
4. Forming Machine and Extension Hopper (Mixer and Machine not shown in Front View)
5. Hoist Motor

Design Obtained from Parschak Machine Co.



SIDE



FRONT

neath the mixer and Operation 6 can be omitted.

Both low and high profile material handling equipment, as complete as the ones discussed above, can be equipped with full automation or can be designed to be semi-automatically operated.

Fully automatic equipment transfers aggregates and cement from storage to batcher, performs the batching, transfers materials to the mixer, does the mixing, and finally sends the mix to the forming machine automatically. The operation requires 1.5 operators. A materials man is in charge of receiving the materials and controls their distribution in the bins. An operator, devoting only half of his time, controls and programs the batching, mixing, and handling of materials. The rest of his time is spent attending the forming machine, and also Operation 8, if it is automatic.

The semi-automation of this equipment means that it performs one cycle automatically after an operator has activated it. The operator must follow the sequence of the operation and from the control panel activate each stage. He cannot attend other operations. Two men, himself, and a materials man are required to operate the equipment.

So far two types of equipment have been described. Both have the option to be operated automatically or semi-automatically, and the same characteristics of performance. In the classification of material handling and concrete making equipment represented in Table 5-1, the type of equipment discussed above belongs to Level of Technology II, and the automation and semi-automation options are desginated as sets II_1 and II_2 respectively.

Sometimes backup storage is used either because of the difficulty to obtain materials every day, or because a higher level of technology is desired. A backup aggregate storage system may be nothing more than a pile of material on the ground or it may consist of concrete stave silos with complete automation and overall capacity to hold 2,500 tons of aggregates (enough for 20 shifts producing 10,000 standard units per shift). Backup cement storage can be provided by having a bigger cement silo or a second silo hooked to the original one.

A pile of aggregates on the ground would not require modification of equipment of Level II at all. A front-loader truck is added to the system to bring materials from piles to hopper. The front-loader operator substitutes the materials man. The plant operation is just as before and requires 1.5 or two men for automatic or semi-automatic equipment respectively.

On the other hand, concrete silos for backup aggregates storing permit a more mechanized system and reduces the labor required. Backup storage systems of this kind are used to backup the operation of automatic material handling plants like the one classified under set II_1. Such a combination is classified as the highest level of automation available for this stage of the process. In Table 5-1 it is presented as the Level of Technology I.

Technology Level I is similar to Technology Level II except that aggregates are transfered automatically from the backup silos every time the bins get to a given level. The rest of the operation is performed as explained for set II_1. Figure 5-10 presents a layout of this class.

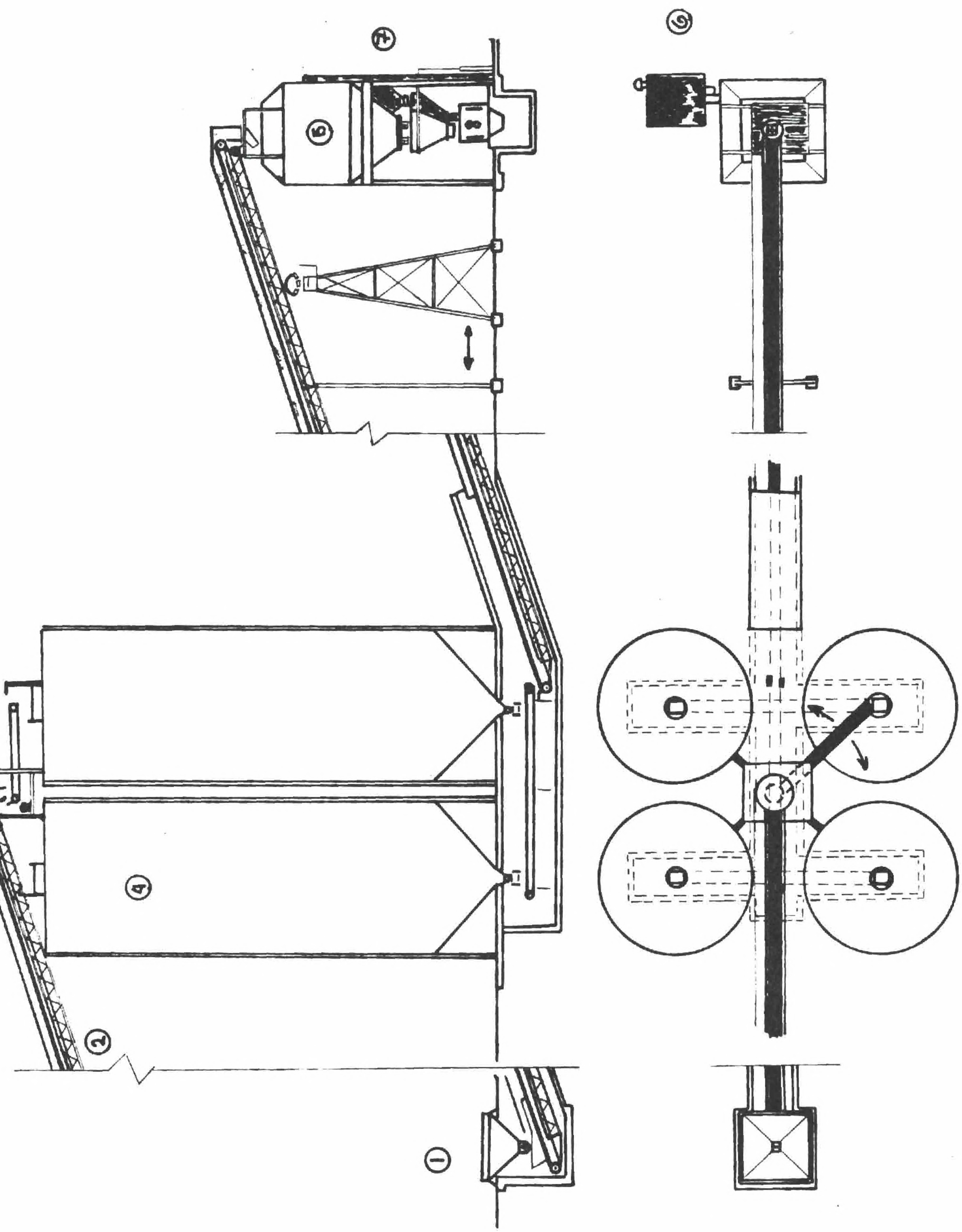
Even though the equipment becomes more complex the operation is carried out much simpler than in Level II, and only requires o.5 man-time.

Figure 5-10. Materials Handling Equipment with Backup Aggregate Storage

The materials are received from the suppliers in a Truck Hopper and conveyed to the Aggregate Silos by a Belt Conveyor. Different Aggregates are distributed to each silo by means of a Rotatory Conveyor. Materials are reclaimed as needed and trasnported to the Aggregates Bin.

1. Truck Hopper
2. Belt Conveyor
3. Rotatory Conveyor
4. Aggregates Silos
5. Aggregates Bin
6. Cement Silo
7. Aggregates and Cement Batchers
8. Mixer
9. Skip Hoist's Pit

Design Obtained from Besser Co.


1
2
3
4
5
6
7

The materials man is substituted by the automation on the backup storage system.

To finish up with the discussion of materials handling and concrete making technology Levels I and II a fact should be pointed out. The progress towards automation in the concrete block process started at the materials handling and concrete making stage since the basic technology had been developed previously for the cement production and ready-mix production. The adaptation to the concrete block production process was relatively easy. Most concrete block manufacturers in the United States have adopted automatic or semi-automatic type of equipment for it offers many advantages over less sophisticated equipment. The most important of this advantages are: 1) easier flow of materials which facilitates the task greatly and offers better working conditions; 2) several aggregates can easily be handled which makes it easy to change from one type of concrete to another; 3) ensuring the concrete output requirements which in turn ensures a constant block production rate without affecting the block-forming machine/block handling equipment capacity; 4) high quality, uniform concrete is produced without extra effort; 5) less supervision required; 6) finally, it should be said that all these advantages permit to concentrate in the block handling and curing stages, which increase the productivity of the plant, and the quality of the product respectively.

<u>Material Handling and Concrete Making</u>

<u>Level of Technology III</u>

Having described the two higher levels of technology we recall from page 135 that besides the aggregates bins storage may also be in piles on the ground. Based on aggregates stored on the ground and silos still kept for cement handling, the third level of technology can be described.

In brief, the operation is carried out as follows. A front-loader truck brings materials (Operation 2) from piles to the aggregates batcher. The cement, on the other hand, (yet stored in a silo) is conveyed to the cement batcher by means of a screw conveyor. The batching can be done by weight or volume. Since these two alternatives involve some differences in the total cost of the equipment, and the accuracy of them in the proportioning task, they bring up two variants within Level of Technology III: sets III_1 and III_2 respectively. Refer to Table 5-1. Figures 5-11 and 5-12 show a typical layout for each variant.

When batching is done by weight the fork-lift truck deposits the aggregates on a batcher hopper and the batcher man weighs it. Based on the weight he proportions the cement. As shown in the figure the batch of aggregates is conveyed to the mixer by a belt conveyor. The cement is dumped into the mixer in its turn. The water is again measured in the mixer with an electric resistance measuring the tickness of the mix. After mixing the concrete is transfered to the forming machine by a skip-hoist.

When batching is done by volume (Figure 5-12) the fork-lift truck operator deposits the aggregates directly into the mixer. The fork-lift's scoop has certain capacity, and the operator promptly learns to pick up the right amount within a very good approximation to the target weight. The cement is transfered from the silo by means of a screw conveyor which

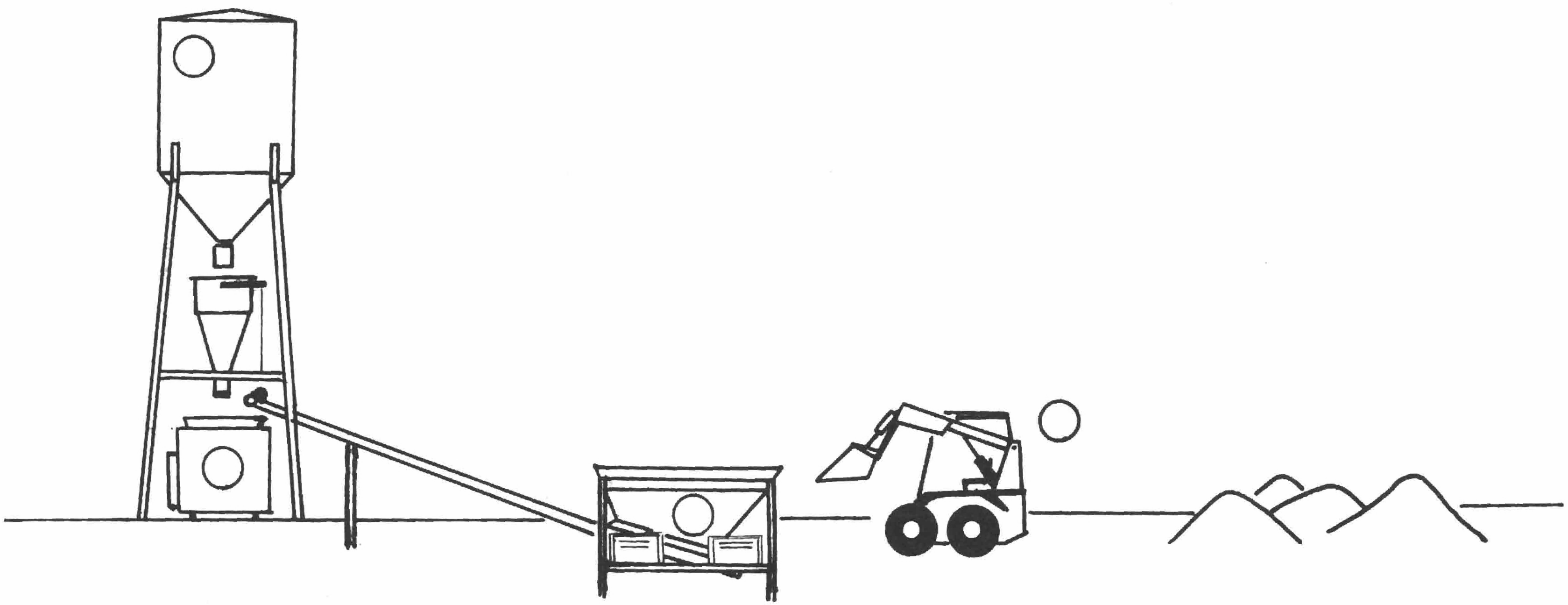


Figure 5-11. Material Handling Equipment with Aggregates Stored on the Ground and Cement in a Silo

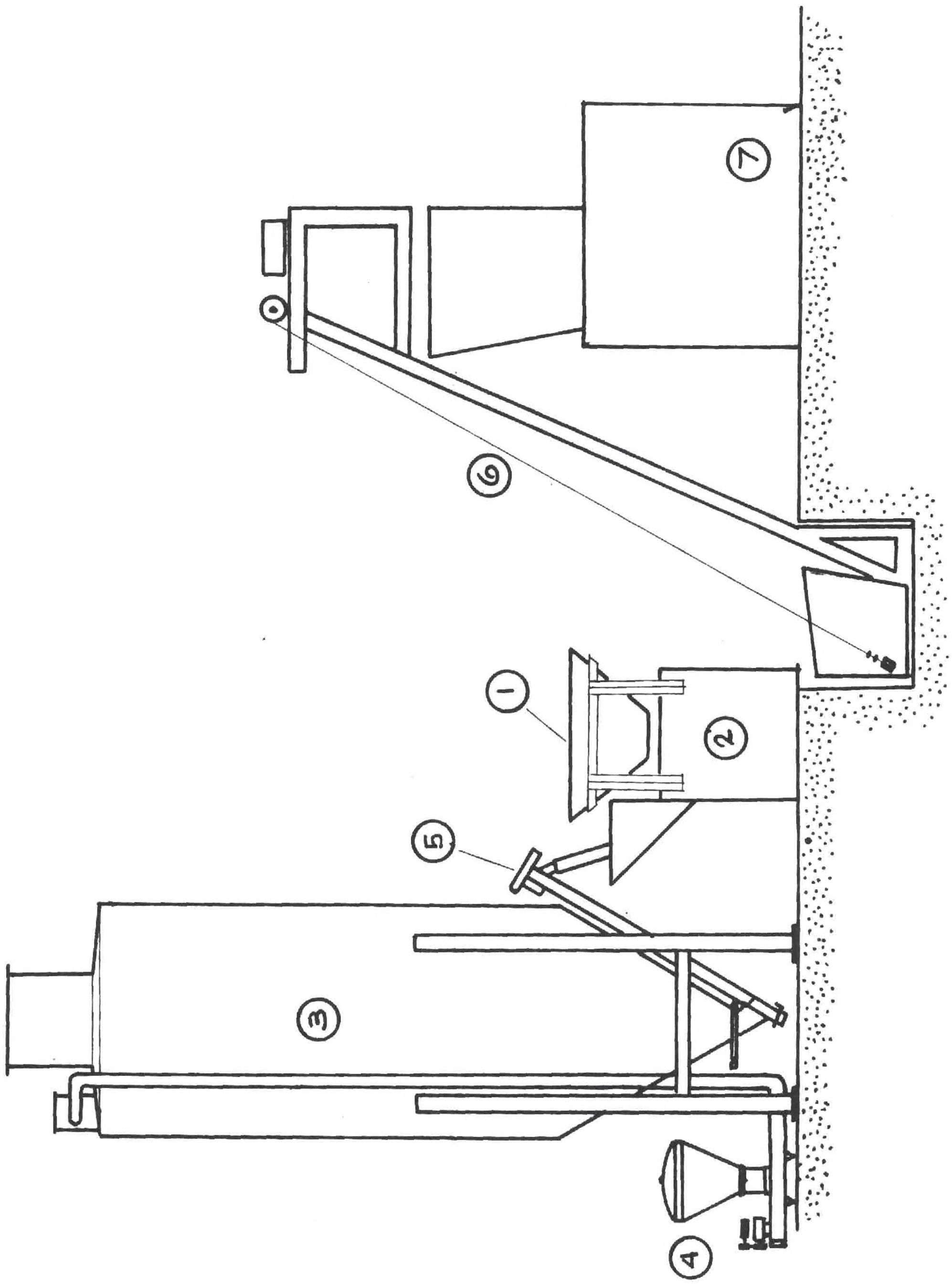
1. Front-Loader Truck
2. Aggregates Weight Batcher
3. Cement Silo
4. Cement Weight Batcher
5. Mixer

Figure 5-12. Material Handling Equipment with Aggregates Stored on the Ground and Cement in a Silo

The aggregates are brought by a Front-Loader Truck and deposited in a Hopper on top of the Mixer. Cement Silo equipped with Pneumatic Pump and Screw Conveyor.

1. Hopper
2. Mixer
3. Cement Silo
4. Pneumatic Pump
5. Screw Conveyor
6. Skip Hoist
7. Forming Machine

Design Obtained from U-Cart Concrete Systems, Inc.


1
2
3
4
5
6
7

has the characteristics of delivering accurate amounts of material per unit of time. The variability is low. A small timer is installed to the controls to have the screw conveyor work for a determined length of time every batch. The water is measured as explained above.

The operation of equipment of this level is not complicated. The labor needs no experience or background on operating machinery. In total three men are required for the operation: a fork-lift truck operator, a batcher man, and a mixer man.

To finish the discussion of technology Level III it is important to contrast it with Level II, and pinpoint some difference between sets $III_1$and III_2.

While equipment of Level II is capable to handle more than two types of aggregates per batch, equipment of Level III presents some difficulties to do so. The reason is that the fork-lift has to make one trip for each aggregate on every batch, so that more than two types of aggregates per batch would increase the time needed to make a batch of concrete and the overall plant production output would decrease. This equipment is designed for concrete blocks plants which usually produce blocks made out of the same two aggregates all the time due to their limitations to handle more than two types of aggregates.

Regarding sets III_1 and III_2 it must be recognized that set III_2 has some flaws which may be important to avoid: 1) since the mixer is placed close to the blockforming machine and the fork-lift has to bring the aggregate to the mixer on every batch, the forming area can easily become crowded resulting in poor working conditions which can cause accidents and/or decrease in productivity; 2) if the batch proportions have to be changed to obtain a different type of concrete the fork-lift truck operator will take some time before he can deliver acceptable uniform proportions of materials to the mixer; this disturbs the concrete output and the block output decreases; 3) the two facts mention above present difficulty to meet concrete output requirements, and more important, the quality of the concrete obtained and consequently of the block produced is not uniform in most cases resulting in a production of poor appearance. When the block manufacturer has to compete in quality it is advisable to use material handling and concrete making equipment of type III_1 over III_2, and if possible and economically feasible, adopt equipment type II_2 over III_1 when the difference in cost/ton of concrete produced is not too big. Also it is advisable not to use equipment type III_2 for high production outputs (this is indicated later on this chapter).

Material Handling and Concrete Making

Level of Technology IV

The equipment classified under Level IV is yet simpler than that of Level III. At this level the aggregates are still brought to the mixer by fork-lift truck, and proportioned by volume in the same way as in set III_2; however, the cement is not handled by bulk anymore, and neither silo nor cement batcher are used.

Sacks of cement weigh 94 pounds and contain one cu. ft. As a result, cement batching is accomplished easily, i.e., a 1:2:4 batch of cement contains one sack of cement, 188 pounds of fine aggregate, and 376 pounds of coarse aggregate. The water is deposited directly into the mixer and measured either with an electrical resistance or with a water meter installed in the water pipeline or hose. A skip-hoist is used to transfer the mix to the forming machine.

The same type of labor skills as for Level III are required; however, for different capacities the number of men changes. This is discussed in Part 2 of this chapter.

Handling cement in the way described reduces greatly the handling capacity and only low production plants can be attended.

Material Handling and Concrete Making

Level of Technology V

The equipment classified under Level of Technology V, consists of the same equipment just described above; however, the aggregates are not carried by a fork-lift truck, instead wheel barrows are used.

When measuring is done with wheel barrows, each barrow should have marks on the inside for one cu. ft., two cu. ft., etc. This marking can be done by dumping a cubic foot box or cement sack full of material in the barrow, leveling and making a mark at that level. This can be done with another cubic foot of material, etc., until the barrow is calibrated.

Even though more labor is needed, the skills of a fork-lift operator are not required any more. Barrowers need no experience and can learn the job in a few days. One worker can handle the cement sacks, and another one the mixer and skip-hoist. Details on the number of barrow men needed for a given capacity are shown in Table 5-4.

Since the materials are heavy, it is not possible to handle much material in this way; and high production plants are impossible to be attended with equipment of this sort.

Materials Handling and Concrete Making

Level of Technology VI

The equipment used at this level is very much limited in its capacity, and it is hand-powered. The aggregates are carried, as in Level V, by wheelbarrow and cement handled in sacks.

Within this level two variants are found. The mixing can be done with a manual mixer or by shovel.

In the first case the materials are deposited into the mixer and a worker maneuveres a handle making the mixers drums rotate, at least for one or two minutes, until the mix is ready.

When mixing is done by shovel the materials are placed on the platform and mixed thoroughly. Although first-class concrete can be mixed by hand, machine mixing is prefered because it results in more thoroughly mixed materials and uniform batches.

Some other ways to measure materials that fit in this level are discussed below.

1. Aggregates can be measured easily by using a bottomless box made to hold exactly one cu. ft., two cu. ft., or any other volume desired. To measure the materials the box is placed on the mixing platform and filled. When the required amount of material has been placed in it, the box if lifted and the material remains on the platform. The cement is already proportioned; each sack of cement contains one cubic foot or 94 pounds.

2. Pails are often used for proportioning materials. For example 1:2:4 batch of cement could be measured by using one pail of Portland Cement, two pails of fine aggregate, and four pails of coarse aggregate.

3. Measuring can be done with shovels, observing carefully the numbers of shovelfuls taken in handling exactly one cubic foot of material. This is done by counting the number of shovelfuls of each aggregate required to fill a cubic foot box or a cement sack. This test should be made at least once each day, particularly if new loads of material are delivered on the job.

For this type of equipment is hard to estimate accurately the number of men required, but at least two men are required for a small job. One to carry the materials and another to do the mixing.

Part 2. Selection of Material Handling and Concrete Making Equipment

The objective of this part is to present estimations of total initial cost, and labor and power requirements for material handling and concrete making equipment of each level of technology. This data was obtained from analyzing suitable equipment of each technology level for predetermined brackets of block production output. Based on the block output requirements the volume of materials to be handled was estimated and in turn the size and technology levels suitable for that particular output were established. How the brackets of output were established, and how the estimations of initial cost, and labor and power requirements were obtained is discussed below.

Table 5-2 presents the technology levels which were analyzed for each bracket of production output, i.e., equipment classified under Level I was analyzed for four brackets of block output: 17-23,000; 14-16,000; 11-13,000; and 8-10,000. The analysis yields data on the

Table 5-2. Brackets of Capacity Analyzed for the Sets of Materials Handling and Concrete Making Equipment Within Each Technology Level

Capable to meet concrete requirements for the following block production output. (Std. Block/8-Hr. Shift)		TECHNOLOGY LEVEL							
	SET I_1	SET II_1	SET II_2	SET III_1	SET III_2	SET IV_1	SET V_1	SET VI_1	SET VI_2
17-23,000	■	■	■						
14-16,000	■	■	■						
11-13,000	■	■	■						
8-10,000	■	■	■	■					
6- 7,000		■	■	■	■				
3- 5,000				■	■	■			
1- 2,000						■	■		
0- 1,000							■	■	■

initial costs, labor, and power, which are presented in Tables 5-3, 5-4, and 5-5 respectively.

To decide what technology levels should be analyzed for each bracket of capacity, it was observed what type of equipment is usually used in practice for each bracket of capacity on Table 5-2. In addition, assistance from equipment manufacturers was requested, and physical (or technical) feasibility studied for each proposal. It must be mentioned that Table 5-2 presents capacities of sets of equipment which work as material handling and concrete making units. Consequently, equipment of low technology levels offer low capacity. However, several sets of equipment (material handling and concrete making units) of low technology levels can operate in combination to provide high capacity. The characteristics of quality of the concrete obtained prevail. Regarding this comment it should be said that many sets of equipment working together would greatly complicate the operation and result in very low productivity.

The figures of costs are not exact as in the case of the equipment described and costed in preceding chapters. Again, the lector should not use the data as a price list. The numbers presented are only an average of how much would the equipment under consideration cost. The figures on labor required present an idea of both the type and amount of labor required. Despite of the fact that the analysis has been made consciously, once again, the reader shall not attempt to use the data as true unless he is certain that his is a situation exactly equal to the one he is pinpointing on this paper. The same applies for estimations on energy requirements.

The possible combinations to design a material handling plant are endless. It is not the intention of this research to cover all of them, but try to classify them under types of equipment available (so called levels of technologies). Perhaps the reader can figure out several setups not included in this pages. However, it is very likely that such a setup fits in some place on Table 5-1 and its initial cost, and labor and power requirements agree with the figures given in Tables 5-3, 5-4, and 5-5.

There are some other assumptions that were made to design and cost out the equipment for each bracket of capacity.

1. About the mixer, it was ruled that its capacity should be such that about 48 batches per shift were mixed. This has its grounds on recommendations and proposals made by equipment manufacturers. Forty eight batches per shift yields ten minutes between batches which is a conservative figure. For a production of 13,000 standard blocks per shift, about 3,400 cu. ft. (126 cu. yd.) of concrete are needed. Thus, (3,4000 cu. ft. per shift)   (48 batches per shift) = (70.1 cu. ft. per batch). Then the capacity of the mixer is assumed to be 75 or 80 cu. ft.

2. The size of the aggregate bins were assumed to hold material for one shift, while the cement silos shall have capacity for five shifts. Of course this assumption should be changed according to the requirements, and materials availability of a particular plant.

3. The type of batching system was based on what is usually found on existing plants with the different types of equipment. Usually weight batchers for high production plants, simply weight or volume batchers are used in medium plants, and volume batching (with no batcher) in low capacity plants.

4. Sizes and capacity of conveyors are assumed to be the same as

those used for plants of the same capacity.

Even though the components to set up a materials handling plant are standard, every plant is designed to suit its own requirements. It is hard to find a system exactly equal to another. The capacities of mixers, batchers, bins, and/or silos, and conveyors have to be established for a particular plant.

Equipment manufacturers offer the best advice to design a plant, but there is some data to be furnished:

1. Required standard blocks or equivalent production output per shift, and number of shifts per day.

2. Type of materials to be used and their proportions.

3. Availability of materials.

4. Type of forming machine, block handling equipment, and curing treatment of the plant.

Based on these data the plant is designed, starting with the forming machine and working backwards through the plant.

With these grounds, our assumptions, and information collected, sets of equipment were designed for each level of technology and capacities under consideration (see Table 5-2). The figures of cost, labor, and power were then obtained.

Table 5-3 contains the figures on total initial cost of equipment.

The first column represents brackets of production output. The rest of the columns each leveled with its corresponding technology level and set within each level stand for the total initial cost of equipment, i.e., the total initial cost of the material handling and concrete making equipment for a concrete block plant with a capacity to produce 8,000 to 10,000 standard blocks per shift would be:

Table 5-3. Total Cost of the Material Handling Equipment for the Various Levels of Technology (Thousands of U.S. Dollars)

Production Output (Std. Blocks/ 8-Hr. Shift)	Equipment Available Technology Level								
	I	II		III		IV	V	VI	
	I_1	II_1	II_2	III_1	III_2	IV_1	V_1	VI_1	VI_2
17-23000	280	185	160	--	--	--	--	--	--
14-16000	260	180	150	--	--	--	--	--	--
11-13000	240	165	130	--	--	--	--	--	--
8-10000	220	140	110	65	--	--	--	--	--
6- 7000	---	125	90	57	46	--	--	--	--
3- 5000	---	---	---	50	40	22	--	--	--
1- 2000	---	---	---	--	--	18	12	--	--
100- 1000	---	---	---	--	--	--	11	3	1

\$220,000 for equipment of set I_1
140,000 for equipment of set II_1
110,000 for equipment of set II_2
65,000 for equipment of set III_1

The labor required to operate each type of equipment is summarized in Table 5-4. Data of labor is presented as a fraction of man-time per shift, i.e., 1.5 means that one man is needed full time at the operation, and only half of the time of a second man is needed.

Table 5-5 contains estimations of horsepower installed in the equipment to calcualte the energy consumption. It was obtained adding up the horsepower of all the electric motors that drive the system. It includes mixer, skip-hoist, belt and screw conveyors, pumps, etc. These figures were estimated along with the figures of initial cost; as a set of equipment was designed the horsepower for each component was recorded and then added up. Again the figures are averaged, i.e., an 80 cu. ft. mixer from different manufacturers has 75, 75, 75, and 80 horsepower, thus, whenever an 80 cu. ft. mixer is considered it is assumed to count for 75 horsepower.

Table 5-4. Labor Required for Each Level of Technology at Different Capacities (Man-Time Per Shift)

Production Output (Std. Blocks/ 8-Hr. Shift)	Equipment Available Technology Level								
	I	II		III		IV	V	VI	
	I_1	II_1	II_2	III_1	III_2	IV_1	V_1	VI_1	VI_2
17-23000	0.5	1.5	2.0	---	---	---	---	-------	-------
14-16000	0.5	1.5	2.0	---	---	---	---	-------	-------
11-13000	0.5	1.5	2.0	---	---	---	---	-------	-------
8-10000	0.5	1.5	2.0	3.0	---	---	---	-------	-------
6- 7000	---	1.5	2.0	3.0	3.0	---	---	-------	-------
3- 5000	---	---	---	3.0	3.0	3.0	---	-------	-------
1- 2000	---	---	---	---	---	2.0	6.0	-------	-------
100- 1000	---	---	---	---	---	---	4.0	2.0-4.0	2.0-4.0

Table 5-5. Total Installed H.P. for the Material Handling and Concrete Making Equipment for the Various Levels of Technology (H.P. Installed)

Production Output (Std. Blocks/ 8-Hr. Shift)	Equipment Available Technology Level								
	I	II		III		IV	V	VI	
	I_1	II_1	II_2	III_1	III_2	IV_1	V_1	VI_1	VI_2
17-23000	240	190	190	--	--	--	--	--	--
14-16000	210	150	150	--	--	--	--	--	--
11-13000	180	130	130	--	--	--	--	--	--
8-10000	165	90	90	70	--	--	--	--	--
6- 7000	---	---	---	50	50	--	--	--	--
3- 5000	---	---	---	30	30	15	--	--	--
1- 2000	---	---	---	--	--	12	12	0	0
100- 1000	---	---	---	--	--	--	12	0	0

CHAPTER VI

AN ILLUSTRATIVE EXAMPLE TO SELECT THE APPROPRIATE TECHNOLOGY LEVEL FOR BLOCK PRODUCTION

The objective of this chapter is to develop an example showing how to use the information provided in preceding chapters to select the appropriate technology level for the production of concrete blocks.

Methodology of Evaluation and Selection

The criterion of evaluation is the unit manufacturing cost which is calculated for each type of available equipment for the four stages of the process. The manufacturing cost involves, for our purposes, only direct labor and factory overhead.

Direct labor is assumed to be the labor needed to accomplish the stages of the production process; from receiving the raw materials to yarding cubes of blocks. In order to illustrate how the labor cost affects the unit manufacturing cost, and consequently the choice of technology, five "levels of labor cost" are considered. These levels of labor cost intend to represent situations where the cost of labor is different and were obtained averaging, for each situation, the hourly wages of the types of labor needed in the process. The averages obtained, labor cost levels, are only used to distinguish one labor cost situation from the others. The cost of direct labor is calculated in the example based on data presented in Table 6-1, which shows the hourly wages for each of the types of labor needed in the process. The function of each

Table 6-1. Hourly Cost of Labor for Each Type of Skills Required in the Process

Type of Labor	Cost of Labor/Hr. for Five Labor Cost Levels*				
	$3.41/Hr.	$2.39/Hr.	$0.832/Hr.	$0.625/Hr.	$0.416/Hr.
Mechanic/Operator	3.90	2.73	1.226	0.920	0.613
Fork-Lift Operator	3.71	2.60	0.817	0.613	0.409
Front-Loader Operator	3.71	2.60	0.817	0.613	0.409
Machine Operator	3.50	2.45	0.976	0.732	0.488
Cuber Operator	3.50	2.45	0.817	0.613	0.409
Offbearing Hoist Man	3.50	2.45	0.817	0.613	0.409
Curing Man	3.50	2.45	0.817	0.613	0.409
Materials Man	3.50	2.45	0.817	0.613	0.409
Offbearer Man	2.90	2.03	0.683	0.513	0.342
Cubing Man	2.90	2.03	0.683	0.513	0.342
Hand-Truck Man	2.90	2.03	0.683	0.513	0.342
Pallets Man	2.90	2.03	0.683	0.513	0.342
Laborer	2.90	2.03	0.683	0.513	0.342

*The term "average labor cost level" is used only to distinguish the five levels of labor cost considered. It represents the average labor cost of all the types of labor for each level considered; however, the direct labor is not claculated with this number but it is based on the cost of each particular labor type needed.

type of labor was explained in preceding chapters.

The factory overhead includes only the following components:

1. Cost of capital invested on productive or handling equipment, and cost of capital invested on in-process block inventory. The capital cost rate considered in the analysis is 18%.

2. Depreciation. The method used to amortize the investment on equipment is the straight line method assuming 15 years of life and no salvage value at the end of this period.

3. Maintenance. Maintenance cost is assumed to be five percent of the initial cost per year. This percentage is an estimation suggested for equipment manufacturers for analysis of this type.

4. Power, fuel, and water consumption. Power is assumed to cost \$0.03/Kw.-Hr., while water cost is assumed to be \$0.0009/gallon. These figures are estimations obtained from Atlanta Power Company and Altanta Water Service respectively. There are two fuels that can be consumed: gas and oil. Their cost is estimated to average \$0.0024/C.F. for gas, and \$0.24/gallon for oil (#2). These figures were estimated from a cost analysis of fuel consumption made by Johnson Gas Appliances Company.

Buildings and land cost, and administrative expenses are left out of the analysis. The reason is that taking them into account could mislead the manufacturing cost analysis, since the cost of land and cost of construction change for almost every country; also administrative expenses and needs are different between manufacturers of different countries.

<u>Steps of the Cost Analysis Suggested Methodology</u>

<u>Step 1</u>. Based on the production output required, the materials handling and concrete making available technology levels of equipment capable to overcome the concrete requirements are obtained from Table 5-2.

<u>Step 2</u>. The available materials handling and concrete making technology levels are evaluated and the most economic alternative se-

lected. Before the evaluation is done the capabilities and characteristics of the equipment selected for analysis from Step 1, must be analyzed in order to recognize the differences in performance of each alternative equipment. This is recommended to avoid the selection of a given technology whose manufacturing cost is the lowest among the unit manufacturing cost of the technologies under analysis, but whose performance is inferior to some of them. Such inferiority indicates that such equipment should not be considered in the analysis, and if considered, such an inferiority should be justified before the final decision is done. Later on this chapter this recommendation will be illustrated.

The capabilities and characteristics of each technology level are discussed in Chapter V.

Step 3. Based on the production output desired, available combinations of blockforming machine/block handling equipment suitable for air curing and low-pressure steam curing systems are obtained from Table 3-7.

Step 4. The available equipment combinations to carry out the blockforming and block handling stages of the process, both when air curing or low-pressure steam curing are adopted, are costed. The most economic combination of equipment for each curing treatment is selected.

Step 5. The curing manufacturing cost is calculated both for low-pressure steam curing, and air curing systems. As for "materials handling and concrete making," and "blockforming and block handling" manufacturing cost, it only includes direct labor and factory overhead.

The advantages and characteristics of each curing treatment should be analyzed to avoid choosing an inappropriate curing treatment, which would result in poor quality blocks. Chapter IV contains a discussion of each curing treatment available.

Step 6. The total manufacturing cost can now be estimated:

a) For concrete block cured by low-pressure steam;

b) For concrete block cured in air.

The alternative (a) or (b) having the lowest total manufacturing cost is selected as the most appropriate technology level for the concrete block production at a given production output and under current capital and labor costs. It should be kept in mind that such a manufacturing cost is associated only to the productive activity (Stages I, II, III, and IV of the production process) and does not include investment in buildings and land, nor administrative expenses.

Figure 6-1 depicts the steps described above.

It must be kept in mind as explained in Chapters III (page 81) and V (page 168) that Tables 3-7 and 5-2 present data on capacity of sets (or units) of equipment (forming machine/block ahdnling combinations, and materials handling and concrete making respectively), and that several sets (units) of equipment of low technology level (low capacity) can be combined to work together providing an overall high capacity.

Illustrative Example

In the pages which follow an example is worked out following the steps discussed above. The example is based on the following data:

1. Required production output 9,000 standard block per 8-hr. shift, or 2,700,000 standard blocks per year assuming that a year has 300 working days. The company cannot produce less than 9,000 units per shift because of a signed contract with a building company.

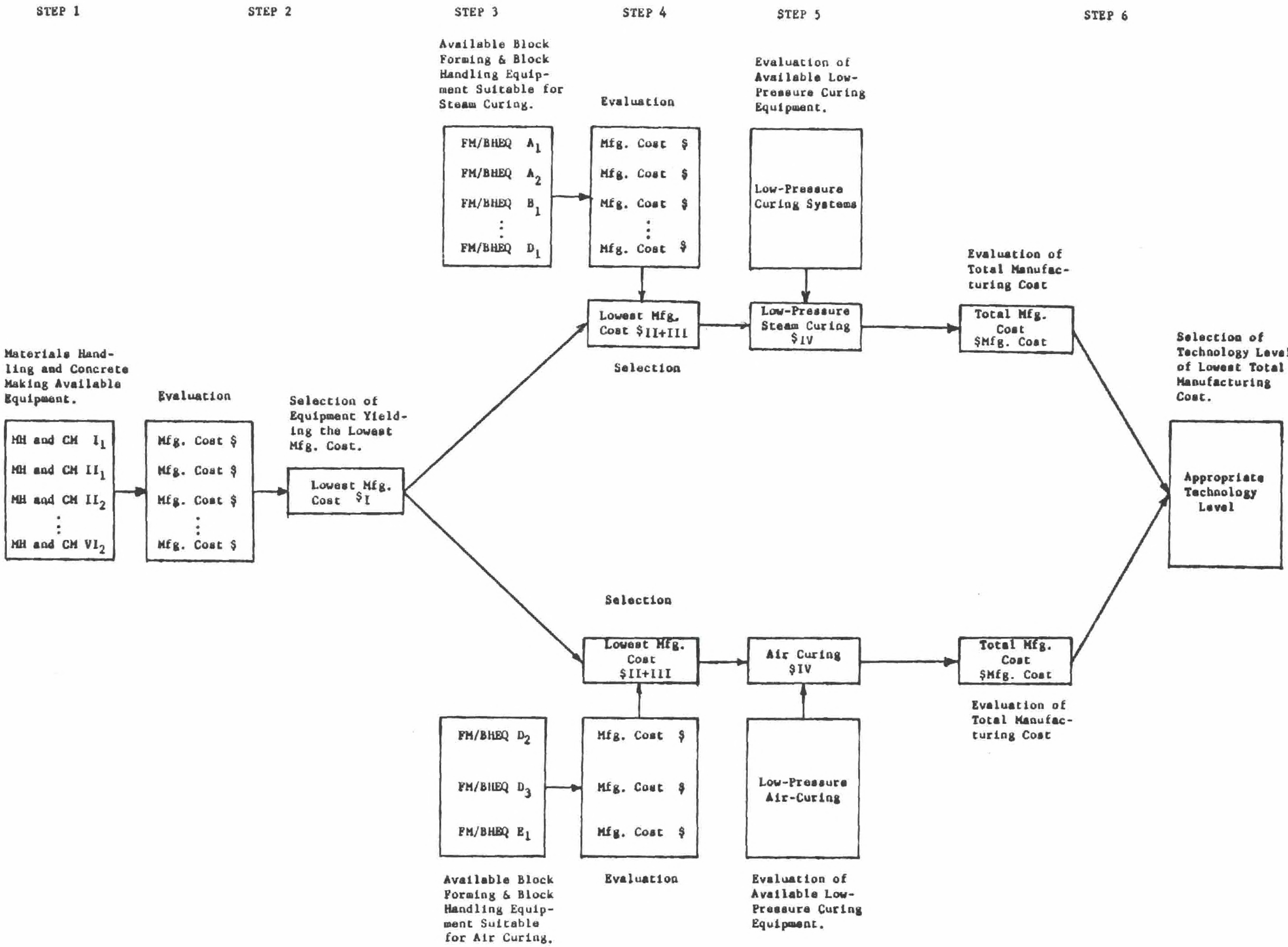


Figure 6-1. Scheme of Suggested Evaluation and Selection Methodology

2. Capital cost 18%.

3. Labor cost is specified in Table 6-1.

4. High quality standards demanded.

5. Several types of block will be produced, i.e., several types of aggregates (more than two) will be handled.

6. Severe weather conditions during the winter and low rain precipitation throughout the year.

<u>Step 1</u>. Available technology levels for the materials handling and concrete making equipment capable of handling the concrete requirements to produce 9,000 standard blocks per 8-hr. shift are from Table 5-2:

I_1: Automatic/bins-silos for in-process storage/automatic backup storage system.

II_1, II_2: Automatic or semi-automatic/bins-silos for in-process storage.

III_1: Mechanized/front-loader/aggregates stored on the ground, and cement stored in silos.

<u>Step 2</u>. Selection of the technology level of materials handling and concrete making equipment.

From Table 5-3 the initial cost of equipment is obtained and summarized below in Table 6-2.

The labor requirements to operate the equipment are provided in Table 5-4 and summarized in Table 6-3.

The power requirements for the material handling and concrete making equipment are provided in Table 5-5 and summarized for our example in Table 6-4.

Table 6-5 presents the factory overhead cost.

Table 6-6 shows a summary of the manufacturing cost analysis for the materials handling and concrete making stage of the process. In this table the unit manufacturing cost of each set of equipment is

Table 6-2. Initial Cost of Materials Handling and Concrete Making Equipment for Available Technology Levels

Set of Equipment	Total Cost	Total Cost Plus 5% for Installation
I_1	$220,000	$231,000
II_1	140,000	147,000
II_2	110,000	115,500
III_1	65,000	68,250

Table 6-4. Power Requirements and Yearly Power Cost

Set of Equipment	H.P.	Kw.	Total Kw.-Hr. Assuming: 75% Usage Factor; 8-Hr. Shifts; 300 Days/Year	Total Power Cost Assuming $.03/Kw.-Hr.
I_1	165	123	221,562	$6,647
II_1	90	67	120,852	$3,626
II_2	90	67	120,852	$3,626
III_1	70	52	93,996	$2,820

Table 6-5. Factory Overhead

CONCEPT	I_1	II_1	II_2	III_1
Interest on Investment	41,580	26,460	20,790	12,285
Depreciation	15,400	9,800	7,700	4,550
Maintenance	11,000	7,000	5,500	3,250
Power	6,647	3,626	3,626	2,820
Total Factory Overhead Due to "MH&CM"* Eq. Only:	$74,627	$46,886	$37,616	$22,905

*Material Handling and Concrete Making

Table 6-3. Labor Requirements and Yearly Labor Cost for Each of the Materials Handling and Concrete Making Equipment Under Analysis

Set of Equipment	Type of Labor and Number	Yearly Labor Cost Under Five Labor Cost Levels				
		$3.41/Hr.	$2.39/Hr.	$0.832/Hr.	$0.625/Hr.	$0.416/Hr.
I_1	Mechanic Operator (.5)	4,680	3,276	1,471	1,104	735
	Total Cost:	$ 4,680	$ 3,276	$ 1,471	$ 1,104	$ 735
	Mechanic Operator (.5)	4,680	3,276	1,471	1,104	735
II_1	Fork-Lift Operator (1)	8,904	6,240	1,960	1,471	982
	Total Cost:	$13,584	$ 9,516	$ 3,432	$ 2,575	$ 1,717
	Machine Operator (1)	8,400	5,880	2,342	1,757	1,172
II_2	Fork-Lift Operator (1)	8,904	6,240	1,960	1,471	982
	Total Cost:	$17,304	$12,120	$ 4,303	$ 3,228	$ 2,152
	Materials Man (2)	16,800	11,760	3,921	2,942	1,963
III_1	Fork-Lift Operator (1)	8,904	6,240	1,960	1,471	982
	Total Cost:	$25,704	$18,000	$ 5,882	$ 4,413	$ 2,944

Table 6-6. Manufacturing Cost of Stage I of the Process

Set of Eq.	CONCEPT	Manufacturing Cost for Five Labor Cost Levels				
		$3.41/Hr.	$2.39/Hr.	$0.832/Hr.	$0.625/Hr.	$0.416/Hr.
I_1	Direct Labor	4,680	3,276	1,471	1,104	735
	Factory Overhead	74,627	74,627	74,627	74,627	74,627
	Mfg. Cost Due to "MH&CM"* Eq. Only	$79,307	$77,903	$76,098	$75,731	$75,362
	Unit Manufacturing Cost:	0.029	0.0288	0.0282	0.0280	0.0279
II_1	Direct Labor	13,584	9,516	3,432	2,575	1,717
	Factory Overhead	46,886	46,886	46,886	46,886	46,886
	Mfg. Cost Due to "MH&CM"* Eq. Only	$60,470	$56,402	$50,318	$49,461	$48,603
	Unit Manufacturing Cost:	0.0224	0.020	0.0186	0.0183	0.018
II_2	Direct Labor	17,304	12,120	4,303	3,228	2,152
	Factory Overhead	37,616	37,616	37,616	37,616	37,616
	Mfg. Cost Due to "MH&CM"* Eq. Only	$54,920	$49,736	$41,919	$40,844	$39,768
	Unit Manufacturing Cost:	0.020	0.0184	0.0155	0.0151	0.0147
III_1	Direct Labor	25,704	18,000	5,882	4,413	2,944
	Factory Overhead	29,905	29,905	29,905	29,905	29,905
	Mfg. Cost Due to "MH&CM"* Eq. Only	$55,609	$47,905	$35,787	$34,318	$32,849
	Unit Manufacturing Cost:	0.020	0.018	0.0133	0.0127	0.012

*Material Handling and Concrete Making

obtained and represents the cost per block produced. This cost is associated only with the materials handling and concrete making stage of the manufacturing process and includes only direct labor and factory overhead.

It can be seen that set of equipment III_1 yields for all the levels of labor cost (except for \$3.4/hr.) the lowest unit manufacturing cost turning out to be from the point of view of unit manufacturing cost the "best" technology to be selected. However, before selecting set of equipment III_1 as the most appropriate technology for the materials handling and concrete making stage of the process, a further thought should be given to this decission bearing in mind the recommendation made in Stage 2 of the cost analysis methodology. Under the circumstances stated in the data for our example, even though set of equipment III_1 yields the lower unit manufacturing cost (see Table 6-8), it would not be advisable to select this equipment because constraint five (see data) is almost impossible to meet. In addition, since several aggregates will be handled, both constraint four, due to contamination of materials, and constraint one, due to handling limitations, will be hard to achieve. It can be concluded that the lower manufacturing cost of set of equipment III_1 would result in a low demand of the blocks produced (loose the contract), and that such alternative must be left out of the analysis. Then, the appropriate technology level would be set of equipment II_2 for all labor cost levels.

Step 3. From Table 3-7 the blockforming machine/block handling equipment combinations suitable for low-pressure steam curing are 4/C, 5/B, and 5/A, while the equipment combination suitable for air curing is 6/D.

a. Available equipment to form the block and handle the block if low-pressure steam curing is adopted.-

From Table 3-6 it can be seen that, due to alternative sets of block handling equipment within the technology Levels A, B, and C, the available equipment combinations to form and handle 9,000 standard blocks per 8-hr. shift curing them by low-pressure steam are:

$4/C_1$, $4/C_2$, $4/C_3$, $4/C_4$, $4/C_5$, $4/C_6$, $4/C_7$,

$5/B_1$, $5/B_2$, $5/B_3$,

$5/A_1$, $5/A_2$.

To simplify the analysis only one combination of each level of technology will be considered: $4/C_5$, $5/B_2$, and $5/A_2$. This is quite arbitrary and the reader should try to consider as many as possible for a better analysis of a particular decision to be made.

b. Available equipment to form and handle block if air curing is adopted.-

From Table 3-7 it can be seen that there is no blockforming machine/block handling equipment combination suitable for air curing (technology Levels D or E) capable to produce 9,000 standard block per eight-hour shift; thus, two equipment combinations capable to produce 4,500 standard blocks/eight-hour shift each have to be used, i.e., two forming machines type six, each with a set of block handling equipment of technology Level D. From Table 3-6 the available sets of block handling equipment of technology Level D are shown to be $6/D_2$ and $6/D_3$ ($6/D1$ is described as suitable for steam curing systems in Chapter III). Again to simplify the analysis only the combination $6/D_2$ is considered.

<u>Step 4</u>. a. Cost analysis of blockforming machine/block handling

equipment combinations for low-pressure steam curing system and selection.-

From Tables 3-1 and 3-8 the initial cost of forming and handling equipment are obtained respectively. Table 6-7 summarizes these data.

Table 6-7. Initial Cost of "Blockforming Machine/Block Handling Equipment Combinations Under Consideration

Equipment Combination	Forming Machine	Block Handling Equipment	Total Cost	Total Cost Plus 5% for Installment
$4/C_5$	115,000	125,000	240,000	$252,000
$5/B_2$	75,000	200,000	275,000	$288,000
$5/A_2$	75,000	270,000	345,000	$362,000

The labor requirements to operate equipment combinations under analysis are presented in Tables 3-9 and 3-9', and summarized in Table 6-8.

The power requirements for each equipment combination are provided in Table 3-10 and 3-1. Table 6-9 summarizes the power cost for each of the equipment combinations under analysis.

Table 6-9. Power Requirements and Yearly Power Consumption Cost

Equipment Combination	H.P.*	Kw.	Total Kw.-Hr./Year 75% Usage Factor 8 Hrs./Day; 300 Day/Year	Total Power Cost Assuming $0.03/Kw.-Hr.
$4/C_5$	60	44.76	80,568	$2,417
$5/B_2$	80	59.68	107,424	$3,223
$5/A_2$	95	70.87	127,566	$3,827

*Forming Machine Included

Table 6-8. Labor Requirements and Yearly Labor Cost for Each of the "Blockforming Machine/Block Handling Equipment" Combinations Under Analysis

Combination	Type of Labor and Number		Yearly Labor Cost Under Five Levels of Labor Cost				
			$3.41/Hr.	$2.39/Hr.	$0.832/Hr.	$0.625/Hr.	$0.416/Hr.
$4/C_5$	Offbearing Hoist Man	(1)	8,400	5,880	1,960	1,471	981
	Cuberman	(7)	48,700	34,104	11,474	8,619	5,745
	Fork-Lift Operator	(2)	17,808	12,480	3,921	2,942	1,963
	Total Cost:		$74,928	$52,464	$17,355	$13,032	$ 8,690
$5/B_2$	Mechanic Operator	(1)	9,360	6,552	2,942	2,208	1,471
	Cuber Operator	(1)	8,400	5,880	1,960	1,471	981
	Fork-Lift Operator	(2)	17,808	12,480	3,921	2,942	1,963
	Total Cost:		$35,568	$24,912	$ 8,824	$ 6,621	$ 4,416
$5/A_2$	Mechanic Operator	(1)	9,368	6,552	2,942	2,208	1,471
	Cuber Operator	(1)	8,400	5,880	1,960	1,471	981
	Fork-Lift Operator	(1)	8,904	6,240	1,960	1,471	981
	Total Cost:		$26,672	$18,672	$ 6,864	$ 5,150	$ 3,434

Table 6-10 summarizes the factory overhead for capital cost rate of 18%.

Table 6-10. Factory Overhead for Equipment Combinations $4/C_5$, $5/B_2$, and $5/A_2$

CONCEPT	$4/C_5$	$5/B_2$	$5/A_2$
Interest on Investment	45,360	51,840	65,160
Depreciation	16,800	19,200	24,133
Maintenance	12,600	14,400	18,100
Power	2,417	3,223	3,827
Total Factory Overhead Due to "BFM/BHEq"* Only:	$77,177	$88,663	$111,220

*Blockforming Machine/Block Handling Equipment

The manufacturing cost analysis of the "blockforming machine/block handling equipment" combinations for the five average labor cost levels considered is presented in Table 6-11. The unit manufacturing cost obtained for each equipment combination represents the cost per block related to the forming and block handling stages of the manufacturing process.

b. Cost Analysis of Blockforming Machine/Block Handling Equipment Combination for Air Curing System.-

From Table 3-1 and Table 3-8 the initial cost of forming and handling equipment are obtained respectively. Table 6-12 summarizes these data.

From Table 3-9' the data on labor requirements to operate the equipment combination $6/D_2$ is obtained and presented in Table 6-13.

Table 6-11. Manufacturing Cost of Stages II and III of the Process

Equipment Combination	CONCEPT	Manufacturing Cost for Five Levels of Labor Cost				
		$3.41/Hr.	$2.39/Hr.	$0.832/Hr.	$0.625/Hr.	$0.416/Hr.
$4/C_5$	Direct Labor	74,928	52,464	17,356	13,032	8,690
	Factory Overhead	77,177	77,177	77,177	77,177	77,177
	Manufacturing Cost Due to Forming Machine/Block Handling Eq. Only	$152,105	$129,641	$ 94,533	$ 90,209	$ 85,867
	Unit Manufacturing Cost:	0.056	0.048	0.035	0.0334	0.032
$5/B_2$	Direct Labor	35,568	24,912	8,824	6,621	4,416
	Factory Overhead	88,663	88,663	88,663	88,663	88,663
	Manufacturing Cost Due to Forming Machine/Block Handling Eq. Only	$124,231	$113,575	$ 97,487	$ 95,284	$ 93,079
	Unit Manufacturing Cost:	0.046	0.042	0.036	0.035	0.034
$5/A_2$	Direct Labor	26,664	18,500	6,864	5,150	3,434
	Factory Overhead	111,220	111,220	111,220	111,220	111,220
	Manufacturing Cost Due to Forming Machine/Block Handling Eq. Only	$137,884	$129,720	$118,084	$116,370	$114,654
	Unit Manufacturing Cost	0.051	0.048	0.044	0.043	0.042

Table 6-12. Initial Cost of "Blockforming Machine/Block Handling Equipment" Combination Under Consideration

Equipment Combination	Forming Machine	Block Handling Equipment	Total Cost	Total Cost Plus 5% for Installment
$6/D_2$ (2)	60,000 (2)	30,000 (2)	180,000	\$189,000

The power requirement for the blockforming machine/block handling equipment combination is only the horsepower required to drive the forming machine since the set of block handling equipment D_2 does not require any power. The cost of power associated to this combination is presented in Table 6-14.

Table 6-14. Power Requirements and Yearly Power Consumption Cost

Equipment Combination	H.P.	Kw.	Total Kw.-Hr./Year 75% Usage Factor 8 Hrs./Day; 300 Days/Year	Total Power Cost Assuming \$0.03/Kw.-Hr.
$6/D_2$ (2)	30 (2)	22.4 (2)	80,640	\$2,420

Table 6-15 summarizes the factory overhead.

The manufacturing cost analysis of the "Blockforming Machine/ Block Handling Equipment" combination $6/D_2$ for a capital cost rate of 18% and five average labor cost levels is presented in Table 6-16.

<u>Step 5</u>. To simplify the analysis only low-pressure direct-fired steam curing, and outdoors air curing systems are evaluated.

Table 6-13. Labor Requirements and Yearly Labor Cost for Each of the "Blockforming Machine/Block Handling Equipment" Combination Under Analysis

Equipment Combination	Type of Labor and Number		Yearly Labor Cost Under Five Levels of Labor Cost				
			$3.41/Hr.	$2.39/Hr.	$0.832/Hr.	$0.625/Hr.	$0.416/Hr.
	Offbearer Man	(2x2)	27,840	19,488	6,557	4,925	3,283
	Cuber Man	(3x2)	41,760	29,232	9,835	7,387	4,925
$6/D_2$ (2)	Pallet Man	(1x2)	13,920	9,744	3,275	2,463	1,641
	Lift-Truck Op.	(1)	8,904	6,240	1,960	1,471	982
	Hand-Truck Man	(6x2)	83,520	58,464	19,670	14,775	9,849
	Total Cost:		$175,944	$123,168	$41,297	$31,021	$20,680

Table 6-15. Factory Overhead for Equipment Combination $6/D_2$

CONCEPT	$6/D_2$
Interest on Investment	34,020
Depreciation	12,600
Maintenance	9,450
Power	2,420
Total Factory Overhead Due to "BFM/BHEq."* Only	$58,490

*Blockforming Machine/Block Handling Equipment

Again, regardless of the results of manufacturing cost analysis the decision maker must analyze the requirements of the production, plant facilities required for each treatment, and the climate of the region in which he is located before making a decision about the curing treatment to be adopted. As mentioned in Chapter IV both treatments can yield good curing results; however, air curing requires optimal circumstances to achieve uniformity in the quality of the production which is not easy to provide for most manufacturers.

Under the constraints assumed in our example given at (page 181) Step two, it would not be advisable to consider outdoor air curing as a suitable curing treatment. Thus, air curing is not taken into account any longer as likely to be adopted for the production of blocks in our example.*

*Air Curing Equipment Evaluation is worked out throughout steps as an illustration.

Table 6-16. Manufacturing Cost of Stages II and III of the Process

Equipment Combination	CONCEPT	Manufacturing Cost for Five Levels of Labor Cost				
		$3.41/Hr.	$2.39/Hr.	$0.832/Hr.	$0.625/Hr.	$0.416/Hr.
6/D_2	Direct Labor	175,940	123,168	41,297	31,021	20,680
	Factory Overhead	58,490	58,490	58,490	58,490	58,490
	Manufacturing Cost Due to Forming Machine/Block Handling Eq. Only	$234,430	$181,658	$99,787	$89,510	$79,170
	Unit Manufacturing Cost:	0.087	0.067	0.037	0.0330	0.029

a. Low-Pressure Steam Curing System Manufacturing Cost.-

The initial cost of the curing system is obtained from Table 4-2. Table 6-17 presents the initial cost of steaming system and kilns. The estimation of kilns cost was made based on building cost data in the United States, and kiln requirements explained in Chapter IV.

Table 6-17. Initial Cost of Curing System Equipment

Direct-Fired Steam Curing System	Steam Generators Cost	Kilns	Total Cost Including 5% for Installment of Eq.
Automatic	16,250	16,000	$33,063
Manual	13,000	16,000	$29,650

Table 6-18 presents data on labor cost for the manual controlled system; automatic equipment needs no labor to be controlled through the curing cycle.

Table 6-18. Labor Requirements and Yearly Labor Cost for Manually Controlled System

Type of Labor and Number	Yearly Labor Cost Under Five Levels of Labor Cost				
	$3.41/Hr.	$2.39/Hr.	$0.832/Hr.	$0.625/Hr.	$0.416/Hr.
Curing Man (1)	$8,400	$5,880	$1,960	$1,471	$ 981

Tables 4-3, 4-4, and 4-5 provide information on water, power, and fuel consumptions respectively, and Tables 6-19, 6-20, and 6-21 summarize their cost per year. Automatic and manual system consume the same quantity of water, power, and fuel on their operation.

Table 6-19. Water Consumption Yearly Cost**

Gallon per Hour*	Cost Per Gallon (Dlls.)	Total Yearly Water Consumption (Gallons)	Water Cost Per Year
180	.0009	162,000	$146

*Steaming Period = 3 Hrs.
**These data may have to be revised.

Table 6-20. Power Cost Per Year

H.P.	Kw.	Total Kw.-Hr./Year Assuming 3-Hr. Steaming Period & 75% Usage Factor	Total Power Cost Per Year Assuming $.03/Kw.-Hr.
7.33	5.47	3,693	$110

Table 6-21. Fuel Consumption Cost Per Year

C.F./Hr. Per Block	Cost/C.F. (Dlls.)	Yearly MCF	Total Cost of Gas	Gal./Hr. Per Block	Cost/Gal. (Dlls.)	Yearly Gallon x 1000	Total Cost of Oil
0.666	0.0024	5,395	$12,948	0.0066	0.24	53.5	$12,830

Table 6-22 summarizes the factory overhead of low-pressure steam curing treatment.

Table 6-22. Factory Overhead

CONCEPT	Automatic	Manual Controls
Interest on Investment	5,951	5,337
Depreciation	1,084	867
Maintenance	812	650
Power	396	396
Water Supply	146	146
Fuel Consumption	12,888	12,888
Total Factory Overhead Due to "Steam Curing" Only:	$21,277	$20,284

Table 6-23 presents the low-pressure steam direct-fired curing manufacturing cost for the capital cost rate of 18%, and the five labor cost levels considered in the analysis. From this Tables it can be seen that low-pressure direct-fired automatic curing system is most economic in any case than low-pressure direct-fired manual curing system.

b. Outdoors Air Curing System Manufacturing Cost.-

The equipment used for outdoors air curing is composed of: (a) pallets not included in block handling equipment; (b) cover for first and second stage of the curing treatment; (c) hose. Details are given in Appendix B. The initial cost of this equipment is summarized in Table 6-24.

Table 6-23. Low-Pressure Steam Curing Manufacturing Cost

Direct-Fired Steam Curing System	CONCEPT	Manufacturing Cost for Five Levels of Labor Cost				
		$3.41/Hr.	$2.39/Hr.	$0.832/Hr.	$0.625/Hr.	$0.416/Hr.
Automatic	Direct Labor	------	------	------	------	------
	Factory Overhead	21,277	21,277	21,277	21,277	21,277
	Manufacturing Cost Due to Low-Pressure Steam Curing	$ 21,277	$ 21,277	$ 21,277	$ 21,277	$ 21,277
	Unit Manufacturing Cost:	0.0080	0.0080	0.0080	0.0080	0.0080
Manual	Direct Labor	8,400	5,880	1,960	1,471	981
	Factory Overhead	20,284	20,284	20,284	20,284	20,284
	Manufacturing Cost Due to Low-Pressure Steam Curing	$ 28,684	$ 26,164	$ 22,244	$ 21,755	$ 21,265
	Unit Manufacturing Cost:	0.0107	0.0097	0.0083	0.0081	0.0080

Table 6-24. Initial Cost of Equipment for Air Curing Treatment

CONCEPT	Total Cost
a. Pallets not included in Block Handling Equipment; 4,500 @ 6.00 each	27,000
b. Cover for First and Second Stages of Curing; 30,000 sq. ft. of sacking @ $.20/sq. ft.	6,000
c. Hose; 200 ft. @ $2/ft.	400
Total Cost:	$ 33,400

The labor required is only one man whose work is to water and cover the blocks.

Table 6-25. Labor Requirements and Cost of Labor

Type of Labor and Number	Yearly Labor Cost Under Five Levels of Labor Cost				
	$3.41/Hr.	$2.39/Hr.	$0.832/Hr.	$0.625/Hr.	$0.416/Hr.
Laborer (1)	$ 6,960	$ 4,872	$ 1,639	$ 1,231	$ 820

Table 6-26 presents the factory overhead of air curing treatment.

Table 6-26. Factory Overhead

CONCEPT	Air Curing System
Interest on Investment (18%)	6,012
Depreciation	2,226
Water Consumption	500
Total Factory Overhead:	$ 8,738

Air curing treatment manufacturing cost is presented in Table 6-27. The unit manufacturing cost shown in this table represents the cost per block cured under air curing treatment and involves the cost of labor required and factory overhead.

Step 6. The components of the concrete block total manufacturing cost are the following:

1. Manufacturing cost related to the materials handling and concrete making stage of the production process (Stage I).

2. Manufacturing cost related to the forming and handling the block activity which is carried out at Stages I and II of the production process.

3. Manufacturing cost related to Stage IV of the process, curing the block.

4. Raw materials cost.

5. Capital cost related to in-process block inventory. The in-process block inventory refers to the interest (or opportunity cost) generated on capital invested to produce blocks which have to stay in the yard due to incomplete hardening (seven days in the case of low-pressure steam and 28 days in the case of air curing). Such a cost is calculated adding up the four components of total manufacturing cost of one shift; the result is multiplied by the yearly capital cost rate, divided by 365 days, and multiplied by the number of days that the blocks are supposed to lay in the yard. The result is multiplied by 300 shifts to obtain the yearly capital cost due to in-process block inventory. (See note on Table 6-28).

The summary of total manufacturing cost of concrete block cured by low-pressure steam treatment is shown in Table 6-28. The unit manufacturing cost presented in this table represents the total manufacturing cost per block produced, and includes the manufacturing cost of the four stages of the production process and the cost of raw materials.

The technology level of the equipment selected for the stages of the process are listed below under the labor cost levels analyzed:

Table 6-27. Air Curing Manufacturing Cost

Air Curing System	CONCEPT	Manufacturing Cost for Five Levels of Labor Cost				
		$3.41/Hr.	$2.39/Hr.	$0.832/Hr.	$0.625/Hr.	$0.416/Hr.
Outdoors	Direct Labor	6,960	4,872	1,639	1,231	820
	Factory Overhead	8,738	8,738	8,738	8,738	8,738
	Manufacturing Cost Due to Air Curing	$15,698	$13,610	$10,377	$ 9,969	$ 9,558
	Unit Manufacturing Cost	0.0058	0.0050	0.0038	0.0037	0.0035

Table 6-28. Manufacturing Cost of Concrete Block Cured By Low-Pressure Steam Using the Most Economic Material Handling and Concrete Making Equipment, Block Forming and Handling Equipment, and Curing Equipment

CONCEPT	$3.41/Hr.		$2.39/Hr.		$0.0832/Hr.		$0.625/Hr.		$0.416/Hr.	
	US Dlls.	Tech. Level	US Dlls.	Tech. Level	US Dlls.	Tech. Level	US Dlls.	Tech. Level	US Dlls.	Tech. Level
CONCRETE BLOCK CURED BY LOW-PRESSURE STEAM MANUFACTURING COST										
M.H. & C.M.* Cost	54,920	II_2	49,736	II_2	41,919	II_2	40,844	II_2	39,768	II_2
B.F. & B.H.**Cost	124,231	$5/B_2$	113,575	$5/B_2$	94,533	$4/C_5$	90,209	$4/C_5$	85,867	$4/C_5$
Curing Cost	21,277	Auto.	21,277	Auto.	21,277	Auto.	21,277	Auto.	21,277	Auto.
Raw Matls. Cost	443,500		443,500		443,500		443,500		443,500	
Inv. Capital Cost	1,483		1,446		2,076		2,058		2,039	
Mfg. Cost	$645,411		$629,534		$603,305		$597,888		$592,451	
Unit Mfg. Cost	0.239		0.233		0.223		0.221		0.220	

*Material Handling and Concrete Making
**Block Forming and Block Handling

Labor Cost Levels: \$3.41/Hr. and \$2.39/Hr.

Selected Equipment:

Stage I. Materials Handling and Concrete Making Equipment Technology Level II_2 (see Table 5-1).

Stages II/III. Blockforming Machine/Block Handling Equipment Combination $5/B_2$ (see Table 3-5).

Stage IV. Low-Pressure Steam Direct-Fired Curing System with Automatic Controls.

Labor Cost Levels: \$0.832/Hr., \$0.625/Hr., and \$0.416/Hr.

Selected Equipment:

Stage I. Materials Handling and Concrete Making Equipment Technology Level II_2.

Stages II/III. Blockforming Machine/Block Handling Equipment Combination $4/C_5$.

Stage IV. Low-Pressure Steam, Direct-Fired Curing System with Automatic Controls.

The combinations of equipment selected for the stages of the process compose the appropriate technology for concrete block production, which results in the lowest unit manufacturing cost.

Recommendations to Select the Appropriate Technology Using this Approach

In this section an attempt is made to indicate some points which are important to accomplish before entering the stage of evaluation and selection of technologies.

1. The desired production output must be established based on the expected demand. This point should provide information not only about the amount of blocks to be produced, but also about 1) specifications of the block to be produced, i.e., quality required, compressive strength required, shape, dimensions, etc., and 2) possibility of future needs to

increase the production due to an increase of demand. The importance of being able to thoroughly answer these questions is that the enterpreneur has to know what will be produced (specifications of it) in order to acquire the appropriate equipment to accomplish his plans, and that by forseeing the future pattern of the business (an especulation) he can acquire equipment which is appropriate for present needs and is also "inexpensively" adaptable to future needs, putting him in a better competitive position.

2. The availability of raw materials (aggregates, cement, and water) is an important aspect in the process of selection of equipment. Depending on the available materials, the specifications of type of block to be produced can be met or not; depending on the frequency of delivery of materials (order lead time) the bins, silos, or area prepared for ground storage should be larger or smaller. Not considering this point can lead the enterpreneur to select equipment which may be appropriate from the point of view of technology; however, it would not be appropriate from the point of view of size requirements, which results in obvious consequences.

3. The types of curing treatments that can be used in that particular region should also be determined at this stage. Type of climate, rain precipitation around the year, desired quality of blocks, amount of blocks to cure, shifts per day, etc., is information needed to know what kind of treatments can be used.

4. Availability of power and fuels in the region should be known and their cost obtained.

5. Type of labor available has to be investigated and a good

estimation of its cost obtained based on the skills required. Unskilled labor can be costly to train resulting in additional cost of the equipment.

6. Before the stage of evaluation and selection of technology the enterpreneur must investigate about financial sources and the interest (cost of capital) that the business will be charged for using this capital. At this point he might not be able to pinpoint a particular source nor the exact cost of capital; however, he can arrive to a figure which will be a very good estimation. The real importance of accomplishing this investigation is that in many countries (specially developing countries) there are special funds for some types of industry and a lower interest can be negotiated. Perhaps a labor-intensive technology which economically is inferior than a capital-intensive technology, can turn out to be more economic than the same capital-intensive technology if a lower interest on borrowed funds is obtained, i.e., a financial incentive policy of a given country to motivate industries to adopt labor-intensive technologies.

7. Finally, it is advisable that the enterpreneur has his first contact with equipment manufacturers in order to identify the equipment which will be offered, and the classifications of technologies herein presented. The request of information should include, if possible, information regarding points one, two, three, and four to facilitate the manufacturers recommending a suitable equipment for those circumstances.

The enterprenuer should not limit himself to the search of new equipment. He must also investigate carefully and thoroughly the possibility of acquiring used equipment which offers the advantages of lower cost. In many cases used equipment can be obtained from a block plant (located most likely in a developed country) who has acquired new equipment and has to sell (sometimes sacrifice) his "old" equipment which is economical incompetent for the situation of that particular plant and country. The point is that such an "old" equipment is called "old," only because there is a more sophisticated equipment now available which needs less labor; however, the so called old equipment still performs perfectly well, produces block of high quality, and has many years of service left.

The possibility of obtaining some of the equipment in the home-country should also be analyzed. The most likely equipment to be produced easily at home are the pallets and racks, specially the latter.

A list of manufacturers is provided in Appendix C. To search for used equipment refer to the following magazines:

1. PIT and QUARRY Publications, Inc.
   105 West Adams Street
   Chicago, Illinois 60603

2. MODERN CONCRETE
   P.O. Box 1953
   Clinton, Iowa 52732

3. CONCRETE PRODUCTS
   300 W. Adams Street
   Chicago, Illinois 60606

Once this stage is accomplished the data provided in this writting will be much better understood and be helpful to lead an enterprenuer contemplating the possibility of investing in the concrete block industry to select the technology which results in lowest unit manufacturing cost for his particular constraints of factors of production.

CHAPTER VII

CONCLUSIONS

The example presented in the preceding chapter can be used to raise some conclusions about the concrete block industry and its appropriate technology.

As a most important finding it can be concluded that there is in fact a significant difference in appropriateness between capital-intensive and labor-intensive technologies available for the concrete block industry. A more competitive position can be enjoyed if the appropriate technology is selected since there is a significant difference between the "unit manufacturing cost" yielded from distinct manufacturing technologies operating under the same labor and capital cost.

From our example, Table 6-28 shows that for labor cost levels below $0.832/Hr a more labor-intensive technology offers the lower manufacturing cost, while for labor cost levels above $2.39/Hr a more capital-intensive technology turns out to be more competitive. It is important to mention that both of the technologies selected in our example as the most appropriate for different levels of labor cost, offer the same quality of output, which is part of the appropriateness of a technology.

The next finding to be discussed pertains to the available technologies for the stages of the manufacturing process. It should be noticed that Stages II and III (forming and handling the block respectively) offer more possibilities to adopt different technologies than Stages I and IV (materials handling and concrete making, and curing respectively). As a result blockforming machine/block handling equipment combinations present best opportunities to balance the intensity of capital and labor to arrive to the most appropriate technology of the overall process. The reason for having a wider variety on types of equipment is that Stage III is not determinant on the quality of the output, while Stages I and IV are directly related with quality. It is important then to bear in mind regarding the selection of appropriate technology that Stages I and IV affect directly the rate of production and the amount of labor employed. This last statement does not mean that quality has nothing to do with Stages II and III, or that rate of production and labor employed is independent from Stages I and IV, but that the rate of production and quality desired, and amount of labor are controlled emphazizing on the corresponding stages of production mentioned above.

To further discuss the statement that blockforming machine/block handling equipment combinations currently available offer most of the opportunities to balance the intensity of capital and labor to arrive to the most appropriate technology of the manufacturing process, some observations are made below based on our example of Chapter VI. It must be kept in mind that this statement assumes that the same quality should be obtained with any of the alternative technologies to be compared.

Table 7-1 shows in what percentage the manufacturing cost of each stage of the process (as presented in the analysis: I, II/III, and IV) forms the total manufacturing cost (excluding cost of raw materials).

From this table it can be seen that the block forming and handling stages of the process compose a large percentage of the total manufacturing

Table 7-1. Percentages Composing the Total Manufacturing Cost of the Stages of the Process (Not Including Raw Materials)

Stage of the Process	Labor Cost Levels					Average % of Cost
	$3.41/Hr.*	$2.39/Hr.	$0.832/Hr.	$0.62/Hr.	$0.416/Hr.	
	%	%	%	%	%	%
I	27.4	26.9	26.5	26.8	26.0	26.6
II/III	61.9	61.5	60.0	59.3	59.1	60.0
IV	10.7	11.6	13.5	13.9	14.9	13.4

*Example from Table 6-28:

I)	Materials Handling and Concrete Making Mfg. Cost	$54,920	27.4%
II/III)	Forming and Handling the Block Mfg. Cost	124,231	61.9%
IV)	Curing Cost	21,277	10.7%
	Total Manufacturing Cost Related to the Stages of the Process Only:	$200,428	100.0%

cost (not including raw materials) which indicates the importance of focussing the attention on it in order to decrease the total cost per block produced.

Another important point to notice is raised from Tables 7-2 and 7-3. Table 7-2 indicates the composition of total yearly interest expenses (capital cost) showing the percentages originated for the investment on equipment for each stage of the process. And Table 7-3 shows the percentage of the total labor cost formed by the labor cost of each stage of the process.

As discussed in the preceding chapter, for our example, technology III_2 at Stage I (materials handling and concrete making) would yield a

Table 7-2. Composition of Interest Expenses on Total Investment

Stages of the Process	LABOR COST LEVELS			
	$3.41/Hr. and $2.39/Hr.		$0.832/Hr., $0.625/Hr., and $0.416/Hr.	
	Yearly Interest	% of Total	Yearly Interest	% of Total
I*	20,790	26.5	20,790	28.8
II/III*	51,840	65.9	45,360	62.9
IV*	5,951	7.6	5,951	8.3
Total:	$78,581	100.0%	$72,101	100.0%

*Data obtained from Table 6-5, 6-10, and 6-22 respectively.

Table 7-3. Composition of Total Labor Cost of the Process

Stages of the Process	LABOR COST LEVELS						
	$3.41/Hr.	$2.39/Hr.	Average % of Total	$0.832/Hr.	$0.625/Hr.	$0.416/Hr.	Average % of Total
	Yearly Interest			Yearly Interest			
I*	17,304	12,120	32.7	4,303	3,228	2,152	19.9
II/III*	35,568	24,912	63.3	17,356	13,032	8,690	80.1
IV*	------	------	----	------	------	-----	----
Total:	$58,872	$37,032	100.0%	$21,659	$16,260	$10,842	100.0%

*Data obtained from Table 6-6, 6-11, and 6-23 respectively.

lower manufacturing cost than that obtained with a higher technology level (II_2); however, due to quality constraints technology II_2 was selected even for low labor cost levels. On the other hand, for the block forming and handling stages, the situation is different; since this stage of the process does not determine the quality of the production, at lower labor cost levels (0.832, 0.625, and 0.416 dollars per hour) a labor-intensive technology ($4/C_5$) turned out to be more economic and then more appropriate that a more capital-intensive technology ($5/B_2$) which was selected as more appropriate for higher levels of labor cost (3.41 and 2.39 dollars per hour). The two Tables (7-2 and 7-3)presented above show this with numbers. The interest expenses originated for investment at Stages II/III is lower ($45,360) for labor cost levels 0.832, 0.625, and 0.416 dollars per hour, than ($51,840) for labor cost levels 3.41 and 2.39 dollars per hour; however, for Stages I and IV the interest expenses are the same for all labor cost levels. On the other hand, the average percentage of total labor cost originated at Stages II and III is higher for labor cost levels 0.832, 0.625, and 0.416 dollars per hour (80.1%), than for labor cost levels of 3.41 and 2.39 dollars per hour (67.3%); however, for Stage I the percentage of labor cost is lower (19.9%) for labor cost levels 0.832, 0.625, and 0.416 dollars per hour than for labor cost levels 3.41 and 2.39 dollars per hour (32.7%).

This has two possible interpretations. One stressing that labor-intensive technologies are appropriate for countries where labor is cheap and capital expensive, and capital-intensive technologies experience the reverse situation. The other observation to be made is that there is a need at the concrete block industry to develop for the Stage I of the process a technology which is capable to produce concrete of the same quality as concrete produced with equipment of technologies I and II, but which is cheaper, i.e., the appropriate technology to produce high quality concrete in countries where labor is cheap and capital expensive.

The suggested approach of evaluation and selection, when applied as recommended, is sensitive to differences between distinct technologies and reflects these differences in terms of economic factors.

Suggested Area for Further Analysis

The number of possible combinations of technologies for the four stages of the process is tremendous. Due to time constraints it was impossible to explore and evaluate all the combinations in this study. Further studies to develop a criteria to optimize the selection of appropriate technology could be done utilizing the data herein provided. Suggested approaches are break-even chart analysis and dynamic programming. A computerized program of either approach would be useful to analyze the appropriateness of every possible combination of technologies for different environments.

APPENDICES

APPENDIX A

CALCULATIONS FOR LABOR REQUIREMENTS

1. Estimation of Labor Required for the Manual Cubing Operation

To estimate the cubing men needed to overcome a production of X blocks per eight-hour shift a multiplicative factor is used. The production output (X) times the multiplicative factor (0.000625) yields a good estimation of cuber men needed to cube such an amount of blocks in an eight-hour shift. This factor is based on a time-motion study. (48)

The average time that a worker needs to pick up a block from a conveyor, lay it out on a cube, and turn back to pick up another block is 18 seconds. Thus, assuming shifts of eight hours,

$$(18 \text{ sec.-man/block}) \div (28{,}800 \text{ sec./shift}) = 0.000625 \text{ man-shift/block.}$$

Now, $$(0.000625 \text{ man-shift/block}) \times (X \text{ block/shift}) = 0.000625\, X \text{ man.}$$

Example. To manually cube 8,000 standard blocks five men are needed, i.e., 8,000 x .000625 = 5.

The multiplicative factor was calculated for standard block units. It would decrease or increase for smaller or bigger blocks respectively.

The factor 0.000625 applies only for set B_3, C_2, and C_3 because the time motion study made assumes that the block is picked up from a conveyor, which is the situation for these sets of equipment.

For sets C_5, C_6, C_7, and C_8 there is a difference. The cubers do not receive the blocks in a conveyor, instead they have to take them down directly from the racks. They work as unloaders and cubers at the same time. Obviously the effort and time is more than before. It has been estimated that taking a block down from a rack, setting it in the cube, and turning back to get another block takes about 25 seconds. As a result the factor turns out to be 0.00085 and is used in the same way as before.

For set C_4 the cubing is made semi-automatically; however, the blocks are unloaded from the racks by hand and a crew of unloaders has to be estimated. The same approach is used, but the time-motion study yields a figure of 15 seconds to take a block down, transfer it onto the conveyor, and turn back to unload another one. The factor turns out to be 0.00053. The figures of unloaders for set C_4 are found under "pallet man."

2. Estimation of a Crew of Hand Truck Men

The estimation of hand truck men needed was made as follows. The cycle has four steps: 1) pick up the cube, 2) carry the loaded hand truck to the yard, 3) set the cube and retire the hand truck, and 4) come back to pick up another cube.

Steps 1 and 3 take 30 seconds each. The time for steps 2 and 4 are in function of the number of cubes produced daily, and the walking speed of a standard worker both with a loaded and empty hand truck.

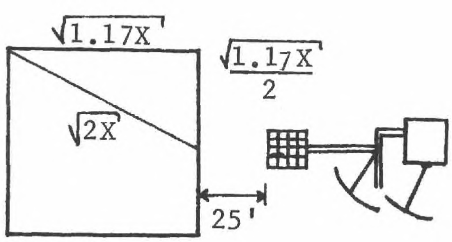
The cubes produced determine the size of the yard. In addition, the curing system determines the length of time the cubes have to stay in the yard. If a plant has a sophisticated curing system that allows them to deliver the blocks as soon as they are cubed, then it is quite illogical to think that they will yard the cubes (if they do it) using a hand-lift truck. So that, we leave this way of yarding to plants with standard curing systems where the blocks have to stay seven days at the yard before delivery, and for not too high production levels which would be as illogical.

First of all an estimation of an average distance per trip is needed:

Production Shift	= X
Standard Block Per Cube	= 24
Number of Cubes/Shift	= X/24
Area taken for a Cube	= 3.6 Sq. Ft. $\approx$ 4.0 Sq. Ft.
Total Yard Area occupied Per Shift	= (X/24) (4) Sq. Ft.
Total Yard Area occupied for Yarding Cubes for seven days (assuming that Blocks are delivered the 8th day after production).	= (X/24) (4) (7) Sq. Ft.

$$1.17(X) = \text{Sq. Ft. of Yard Needed}$$

The square root of 1.17(X) represents the measure (ft.) per side of the yard if it is to be square shaped. Assuming that the yarding starts at 25 feet from the cubing station, the minimum distance to travel would be 25 feet, and the furthest point would be 25 ft. + 2(X) ft. See Figure 1.



Thus, an average distance would be: $(25 + 2X)/2 = \overline{D}$.

Figure 1. Yarding Area

Now, based on an Industrial Engineering Handbook we can figure out that a man walks at a rate of three feet per second. Thus, for step two we assume 1.0 ft./sec. or 60 ft./min., and 1.5 ft./sec. or 90 ft./sec. for step four. (48) The time in minutes for steps two and four would be: $\overline{D}/60$ and $\overline{D}/90$ respectively.

Finally, our equation to determine the average time in minutes per trip that a hand-truck man needs to deliver one cube if the plant produces X blocks/shifts is:

$$\overline{T} = 1 + \overline{D} \times 0.03$$

Now we can easily know how many hand-truck men we need. A shift has 480 minutes, then, $480/\overline{T} = N$; number of trips or cubes a man can make or deliver. And we already know how many cubes we will produce (X/24); then the workers needed are (X/24)/N.

The estimation of hand-truck men needed to carry the pallets of green block from the cable conveyor to the yard was calculated in a very similar way as that of hand-truck men needed for yarding cubes and is explained below.

The cycle has four steps: 1) load the hand-truck with pallets of block (three 3-block pallets or four 2-block pallets); 2) carry the loaded hand-truck to the yard; 3) unload the hand-truck and lay the pallets of blocks on the ground, and 4) come back to the cable conveyor. Steps one and three are estimated to take one minute each, while the time needed for steps two and four is in function of the daily output and the walking speed of a standard worker both with loaded and empty hand-truck.

The blocks produced per shift determine the size of the yard or the distance to be walked every trip from the conveyor to the yard. It is estimated that one square foot is needed per each block to be placed on the ground. Then, assuming that all the production of one shift is set on one side of the cable conveyor, (see Figure 2) the average distance to be walked per trip is $\sqrt{X}/2$ ft., where X is the production output per shift. Then, if the walking speed is assumed to be 1 ft./sec., and 1.5 ft./sec. if the hand-truck is loaded or emptied respectively, the time needed for steps two and four would be,

$$\left[(X/2) \div (1 \text{ ft./sec.})\right] + \left[(X/2) \div (1.5 \text{ ft./sec.})\right]$$

The total time per trip is then,

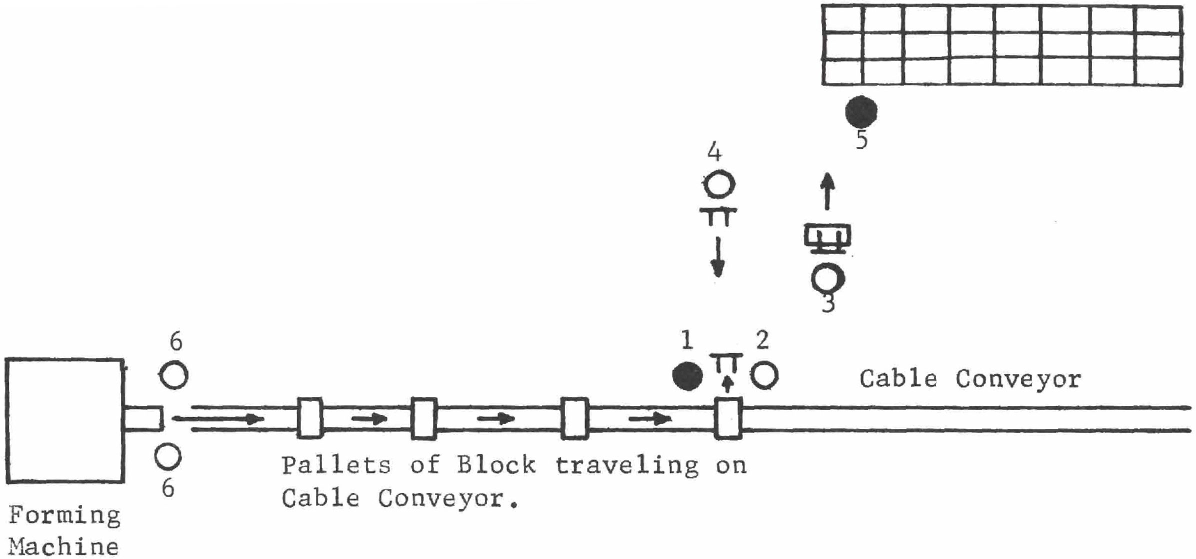
$$T = 120 \text{ sec.} + \frac{X}{2} + \frac{X}{3} = (120 + 0.833\sqrt{X}) \text{ sec./trip}$$

$$\therefore \quad T = (2 + 0.0138\sqrt{X}) \text{ min./trip}$$

Since in every trip eight blocks are carried (four pallets) there are X/8 trips/shift needed; thus, the number of hand-truck men needed is,

$$N = T \times X/8 \div 480$$

In addition, two more men are needed; one to load the hand-trucks at the cable conveyor (helped by the hand-truck man), and other to unload it at the yard (also helped by the hand-truck man).



1. Man loading Hand-Trucks.
2. Hand-Truck man loading Hand-Truck.
3. Hand-Truck man carrying Blocks to Yard.
4. Hand-Truck man coming back from Yard to Conveyor.
5. Man unloading Hand-Trucks.
6. Offbearer men.

Figure 2.

APPENDIX B

ESTIMATION OF EQUIPMENT NEEDED FOR AIR CURING

Outdoors Air Curing

Equipment Needed

1. Pallets not included in block handling equipment. The estimations of cost of block handling equipment includes pallets for one shift operation, but air curing needs pallets for two or three shifts since they cannot be reused until the blocks are cubed.

The cost of extra pallets is:

($/pallet) x (No. of extra pallets).

2. Space needed for first and second stage of curing. Assuming for practical purposes that each block takes one square foot at the first stage, and assuming that the blocks stay 48 hours at this stage, the space needed is:

(2 shifts) x (X blocks/shift) x (1 sq. ft./block) =

(2X) sq. ft. of space for first stage.

The area needed for the second stage of air curing depends both on the rate of production and the means used to transport the cubes from Stage I to Stage II: lift-truck or hand-truck.

In the case of lift-truck, the cubes are usually stacked in stacks of two cubes.

Production Rate	= X Standard Blocks/Shift
Number of Blcoks/Cube	= 126
Number of Cubes/Shift	= X/126
Area taken for a Cube	= 16 ft.^{2}
Total Yard Area	= X/(126 x 2) (16) = (X/252) (16)
Total Yard occupied for yarding through 26 days (assuming delivery at the 28th day after forming, and three days off for each 26 days)	= (X/252) (16) (23) = 1.46 X Sq. Ft.

In the case of hand-truck, and following the same pattern:

Number of Blocks/Cube	= 24
Area taken Per Cube	= 3.6 Sq. Ft.
Total Yard occupied for yarding through 26 days (under the same assumptions)	= (X/24) (3.6) (23) = 3.45 X Sq. Ft.

Thus, the total curing area is the sum of these two results plus 40% allowance for isles, etc. Total curing area = 4.8 X sq. ft. or 7.6 X sq. ft. for the cases of lift-truck or hand-truck respectively.

3. The covering needed is estimated from the sq. ft. of space calculated above (not including allowances).

First Stage: (1.46 X) ($/Sq. Ft. of Covering).

Second Stage: (3.45 X) ($/Sq. Ft. of Covering).

4. Hose. Assuming that there is a faucet between the area for Stage I and II, the length of the hose can be calculated as follows:

$\sqrt{(4.8\ X)}$ ($/Ft. of Hose) for lift-truck case,

or $\sqrt{(7.6\ X)}$ ($/Ft. of Hose) for hand-truck case,

Where $\sqrt{\quad}$ represents the length of one side of the total curing area; a hose so long that can reach any spot of the area for proper watering of the blocks.

Indoors Air Curing

Equipment Needed

1. Pallets not included in block handling equipment. In this case pallets for four extra shifts are needed. Then the cost for extra pallets is:

($/Pallet) x (No. of Extra Pallets).

2. The yarding space needed is calculated as in outdoors curing, but there is no yarding needed for the first stage and only the production of 20 shifts is to be held in storage once they are cubed. Thus, the area needed for lift-truck case is:

(X .252) (16) (20) (1.3 X) Sq. Ft., and

(X/24) (3.6) (20) = 3 Sq. Ft.

3. Room or shed for the first stage of curing. There are many different designs for a shed and the costs can vary greatly from one to another so the calculation was made based on construction rates in the United States for sq. ft. of walls, floor, and roof. Walls are made out of blocks; the floor of cast concrete; and the roof of structural steel and galvanized panels. Total construction cost, roof: $1.25/sq. ft., walls: $1.87/sq. ft.; floor: $1.05/sq. ft.

4. Hose is calculated in the same way as outdoors curing.

APPENDIX C

CONCRETE BLOCK EQUIPMENT MANUFACTUERS

The purpose of this Appendix, which has been based on a Buyers Guide published by Modern Concrete Magazine in September 1977, is to provide names and addresses of concrete block equipment manufacturers. It is divided in three sections: key list, manufacturers-equipment, and manufacturers addresses.

Key List

This section presents a list of block plant equipment.

1. Complete Systems
2. Autoclaves
3. Batchers
4. Mixers
5. Block Machines
6. Block/Brick Molds
7. Block Cubers
8. Block Cube Strappers
9. Block Curing Systems
10. Block Curing Room Doors
11. Block Handling Systems
12. Block Pallets
13. Block Pallet Cleaners
14. Block Palletizers
15. Block Splitters
16. Block Turnovers
17. Masonry Supplies
18. Specially Product Systems
19. Transfer Cars
20. Accessories
21. Fork-Lift and Front-Loader

Manufacturer-Equipment Supplied

Listed below are firms supplying block plant equipment. Following each company name are numbers indicating what they supply according to the preceding "Key List."

AA Wire Products Co., 17.
ATO Construction Equipment Div. (T.L. Smith), 4.
Aggregate Plant Products, Co., 1,3,4.
Alkon Corporation, 3.
American Alloy Steel Inc., 1,3.
Bergen Machine & Tool Co., 4,5,6,7,11,13,14,15,16,20.
Besser Co., 1,3,4,5,6,7,9,11,12,13,14,15,16,18,19,20.
Beverly Steel Corp., 12.
The Boardman Co., 6,12.
W.R. Bonsal Co., 17,18.
Builders Equipment Co., 1,7,9,11,16.
Cardinal Scale Mfg. Co., 3.
Caterpillar Tractor Co., 21.
Christensen Diamond Prods., 17.
Cleveland Vibrator Co., 3.
Columbina Machine Inc., 1,3,4,5,6,7,9,11,12,13,14,15,16,19,20.
Concrete Equipment Co., 3.
Concrete Pipe Machinery Co., 4.
Dan-Dee Equipment, Inc., 3.
W.E. Dunn Mfg. Co., 4,6.
Dur-O-Wal, Inc., 17.
Eirich Machines, Inc., 4.
Elgood Mayo Corp., 19.
Erickson Corp., 11.
Fielding & Platt, Limited, 18.
Firl Industries, Inc., 10.
Fleming Mfg. Co., Inc., 4,5,6,15,18.
H.J. Fuller & Sons, Inc., 3.
GOCORP, Inc., 1,4,5,6,7,11,16,19.
Heltzel Co., 3.
IPA Systems, Inc., 17.
J I Case Co., 21.
Jaeger Machine Co., 4.
C.S. Johnson Co., 3,4.
Johnson Gas Appliance Co., 6,9.
Kent Concrete Equipment, Inc., 4,5,6,11.
The Lithibar Co., 1,5,6,7,8,11,14,15,16,20.
Madison Machine Co., Inc., 6.
Masonry Design Co., 18.
E.L. Moore Co., Inc., 20.
Earl A. Netzband Assoc., 3,4,11,20.
Paco Corp., 1,7,8,9,11,14,16,19.

Pennsylvania Insert Corp., 20.
Portec Inc., Butler Div., 3.
Praschak Machine Co., 1,4,5,7,11,16.
ProSoCo, Inc., 18.
Ramsey Engineering Co., 3,9.
W.J. Savage, 20.
Signode Corp., 8.
R.L. Spillman Co., 3,4,20.
Standley Bin & Conveyor Co., 1,3,9.
Tag Masonry Systems, Inc., 18.
Turmac, Inc., 4.
U-Cart Concrete Systems, Inc., 4.
Unit Metal Fabricators Div. Unit Step (Ontario) Ltd., 3,4,15,18.
Voeller Mfg. Co., 4.
Warren Sales Corp., 18.
Weigh Systems, Inc., 3.
Wisconsin Electrical Mfg. Co., Inc., 3.

Manufacturers Addresses

This section provides the addresses of all the companies mentioned above.

AA Wire Products Co.
6100 S. New England Ave.
Chicago, Ill. 60638
Phone: (312) 586-6700

ATO Construction Equipment Div.
T.L. Smith
P.O. Box 10263
Charleston, S.C. 29411
Phone: (803) 797-5300

Aggregate Plant Products Co.
P.O. Box 1198
San Antonio, Texas 78294
Phone: (512) 333-1111

Alkon Corp.
3042 Mckinley Ave.
Columbus, Ohio 43204
Phone: (614) 486-2957

American Alloy Steel, Inc.
2070 Steel Drive
Tucker, Ga. 30084
Phone: (404) 934-1681

Bergen Machine & Tool Co., Inc.
189 Franklin Ave.
Nutley, N.J. 07110
Phone: (201) 667-7300

Besser Co.
Alpena, Mich. 49707
Phone: (517) 354-4111

Beverly Steel Corp.
P.O. Box 27065
400 East 142nd St.
Chicago, Ill, 60627
Phone: (312) 849-8100

The Boardman Co., Concrete Truck Mixers
P.O. Box 26088
1401 S.W. 11th St.
Oklahoma City, Okla. 73126
Phone: (405) 634-5434

W.R. Bonsal Co.
P.O. Box 38
Lilesville, N.C. 28091
Phone: (704) 848-4141

Builders Equipment Co.
P.O. Box 7143
Phoenix, Ariz. 85011
Phone: (602) 937-4741

Cardinal Scale Mfg. Co.
P.O. Box 151
Webb City, Mo. 64870
Phone: (417) 673-4631

J I Case Co.
700 State St.
Racine, Wis. 53404
Phone: (414) 636-6272

Caterpillar Tractor Co.
100 N.E. Adams St.
Peoria, Ill. 61629
Phone: (309) 675-4835

Christensen Diamond Products
1937 S. 300 West
Salt Lake City, Utah 84110
Phone: (801) 487-5371

Cleveland Vibrator Co.
2828 Clinton Ave.
Cleveland, Ohio 44113
Phone: (216) 241-7157

Columbia Machine, Inc.
107 Grand Blvd.
Vancouver, Wash. 98661
Phone: (206) 694-1501

Concrete Equipment Company, Inc.
P.O. Box 430
237 North 13th
Blair, Nebr. 68008
Phone: (402) 426-4181

Concrete Pipe Machinery Co.
P.O. Box 1708
111 S. George St.
Sioux City, Iowa 51102
Phone: (712) 277-8111

Cardinal Scale Mfg. Co.
P.O. Box 151
Webb City, Mo. 64870
Phone: (417) 673-4631

Dan Dee Equipment, Inc.
P.O. Box 125
35006 Washington Ave.
Honey Creek, Wis. 53138
Phone: (414) 534-3138

Dur-O-Wal, Inc.
601 N. Point Road
Baltimore, Md. 21237
Phone: (301) 485-4120

W.E. Dunn Manufacturing Co.
413 West 24th St.
Holland, Mich. 49423
Phone: (616) 392-3171

Eirich Machines Inc.
663 Fifth Ave.
New York City, N.Y. 10022
Phone: (416) 832-2241

Elgood-Mayo Corp.
140 Varick Ave.
Brooklyn, N.Y. 11237
Phone: (212) 497-5445

Erickson Corp.
211 St. Anthony Blvd., N.E.
Minneapolis, Minn. 55418
Phone: (612) 789-8811

Fielding & Plant Limited
P.O. Box 10, Atlas Works
Gloucester, Glos, England GL1 5RF
Phone: (0452-28611

Firl Inudstries Inc.
321 W. Scott St.
Fond Du Lac, Wis. 54935
Phone: (414) 921-6942

Fleming Mfg. Co., Inc.
P.O. Box F
Cuba, Mo. 65453
Phone: (314) 885-3311

H.J. Fuller & Sons, Inc.
1212 Chesapeake Ave.
Columbus, Ohio 43212
Phone: (614) 486-2921

Gocorp, Inc.
401 Gulf St.
Adrian, Mich. 49221
Phone: (517) 265-7165

Heltzel Co.
1750 Thomas Rd.
Warren, Ohio 44481
Phone: (216) 395-9545

IPA Systems, Inc.
2745 N. Amber St.
Philadelphia, Pa. 19134
Phone: (215) 425-6607

Jaeger Machine Co.
550 W. Spring St.
Columbus, Ohio 43216
Phone: (614) 228-4311

C.S. Johnson Company
P.O. Box 3067
Champaign, Ill. 61820
Phone: (217) 356-3781

Johnson Gas Appliance Co.
520 E. Avenuce N.W.
Cedar Rapids, Iowa 52405
Phone: (319) 365-5267

Kent Concrete Equipment, Inc.
5138 State Rt 43
Kent, Ohio 44240
Phone: (216) 673-0013

The Lithibar Co.
P.O. Box 3008
354 West 14th St.
Holland, Mich. 49423
Phone: (616) 396-5215

Madison Machine Co., Inc.
2815 Sharp Road
Adrian, Mich. 49221
Phone: (517) 265-8532

Masonry Design Co.
P.O. Box 126
Rehoboth, Mass. 02769
Phone: (401) 521-3411

E.L. Moore Co., Inc.
135 Commercial Way
Costa Mesa, Calif. 92627
Phone: (714) 548-9831

Earl A. Netzband Associates, Inc.
P.O. Box 123
112-4th Ave.
Baraboo, Wis. 53913
Phone: (608) 356-9401

Paco Corp.
930 Wellington
Montreal, Que., Canada H3C 1V1
Phone: (514) 861-6768

Penn. Insert Corp.
P.O. Box 556E
DeVault, Pa. 19432
Phone: (215) 644-9304

Portec Inc. Butler Div.
941 Blackstone Ave.
Waukesha, Wis. 53186
Phone: (414) 547-7713

Praschak Machine Co.
P.O. Box 368
Marshfield, Wis. 54449
Phone: (715) 384-2184

ProSoCo, Inc.
P.O. Box 4040
1040 Prallel Pkwy.
Kansas City, Kans. 66104
Phone: (913) 281-2700

Ramsey Engineering Co.
1853 W. County Rd. C
St. Paul, Minn. 55113
Phone: (612) 633-5150

W.J. Savage Co., Inc.
P.O. Box 157
912 W. Clinch Ave.
Knoxville, Tenn. 37901
Phone: (615) 637-9441

Signode Corp.
2600 N. Western Ave.
Chicago, Ill. 60647
Phone: (312) 276-8500

R.L. Spillman Co.
P.O. Box 07847
1701 Moler Rd.
Columbus, Ohio 43207
Phone: (614) 444-2184

Standley Bin & Conveyor Co., Inc.
P.O. Box 800
311 College St.
Cape Girardeau, Mo. 63701
Phone: (241) 334-2831

Tag Masonry Systems, Inc.
P.O. Box 366
St. Charles, Mo. 63301
Phone: (314) 946-6654

Turmac Inc.
P.O. Box 22026
Portland, Oreg. 97222
Phone: (503) 656-5265

U-Cart Concrete Systems, Inc.
P.O. Box 1833
6137 N.E. 63rd
Vancouver, Wash. 98663
Phone: (800) 426-4790

Unit Metal Fabricators
Div. Unit Step (ontario) Ltd.
64 Revell Ave.
Woodstock, Ont. Canada N4S 7X6
Phone: (519) 537-6284

Voeller Manufacturing Co.
P.O. Box 325
Port Washington, Wis. 53074
Phone: (414) 284-3114

Warren Sales Corp.
P.O. Box 11849
Knoxville, Tenn. 37919
Phone: (615) 588-6459

Weigh Systems, Inc.
10210 N. Interregional
Austin, Texas 78753
Phone: (512) 836-5513

Wisconsin Electrical Mfg. Co., Inc.
P.O. Box 140
2501 S. Moorland Rd.
New Berlin (Milwaukee) Wis. 53186
Phone: (414) 782-2340

BIBLIOGRAPHY

BIBLIOGRAPHY

1. ACI Committee 212, "Admixtures for Concrete," ACI Journal, Proceedings V. 41, No. 2, Nov. 1944, pp. 73-88.

2. ACI Committee 716, "High-Pressure Steam Curing," ACI Journal, Proceedings V. 40, No. 5, Apr. 1944, pp. 409-414.

3. ACI Committee 716, "Physical Properties of High-Pressure Steam Cured Concrete Block," ACI Journal, Proceedings V. 49, No. 8, Apr. 1953, pp. 745-756.

4. ACI Committee 613, "Recommended Practice for Selecting Proportions for Concrete (ACI-613-54)," ACI Journal, Proceedings V.51, No. 1, Sept. 1954, pp. 49-64.

5. ACI Committee 212, "Admixtures for Concrete," ACI Journal, Proceedings V. 51, No. 2, Oct. 1954, pp. 113-146.

6. ACI Committee 613, "Recommended Practice for Selecting Proportions for Structural Lightweight Concrete (ACI 613A-59)," American Concrete Institute, Detroit, 1959, 10 pp.

7. ACI Committee 212, "Admixtures for Concrete," ACI Journal, Proceedings V. 60, No. 11, Nov. 1963, pp. 1481-1524. See Section 212, Manual of Concrete Practice.

8. "Autoclave Pioneer Revisited," Concrete Products, V. 65, No. 8, Aug. 1962, pp. 29-45.

9. Bache, H.H., and Wibholm, O.M., "Heat Curing of Concrete," BFL Internal Report No. 102, Concrete Research Laboratory, Karlstrup, 1965, 49 pp.

10. Berkoltch, T.M.; Kheiker, D.M.; Grachva, O.L.; Volkov, O.S.; and Mikhaleevskaya, E.S., "Hydration Processes in the Accelerated Hardening of Cement," Proceedings, RILEM Symposium (Moscow, 1964), RILEM, Paris, Session I/6, 24 pp.

11. "Bibliography on the Accelerated Curing of Cements and Concrete by Steam," Revue des Materiaux de Construction (Paris), No. 557, 1962, pp. 57-63.

12. Butt, J.M.; Timashov, V.V.; and Likatzkaya, L.A., "Acceleration of Cement Hardening at Temperature of 20-100°C," Proceedings, RILEM Symposium (Moscow, 1964), RILEM, Paris, Session I/8, 34 pp.

13. Carlson, C.C., "Lightweight Aggregates for Concrete Masonry Units," ACI Journal, Proceedings V. 53, No. 5, Nov. 1956, pp. 491-508.

14. Chamberlin, W.H.; Brewer, H.W.; and Shideler, J.J., "Compressive Strength of Steam Cured Concrete," Report C-621, Concrete Laboratores, U.S. Bureau of Reclamation, Aug. 1952.

15. Chamberlin, W.H.; Brewer, H.W.; and Shideler, J.J., "Effect of Initia Curing Temperatures on the Compressive Strength and Durability of Concrete," Laboratory Report C-625, U.S. Bureau of Reclamation, 1952.

16. Clifton, David; and David E. Fyffe, "Project Feasibility Analysis: A Guide to Profitable New Ventures," New York: John Wiley & Sons, Inc., 1977.

17. "Concrete Masonry Structures - Design and Construction," ACI Journal, May and June 1970.

18. "Concrete Masonry Handbook," AIA File No. 10-C, Portland Cement Association, Chicago, 1951.

19. Copeland, R.E., "Kilns and Apputenant Facilities for Low Pressure Steam Curing," Technical Report No. 77, National Concrete and Masonry Association, 1968.

20. Davis, R.E.; and Kelly, J.W., "Lightweight Aggregates," Symposium on Mineral Aggregates, Special Technical Publication No. 83, ASTM, 1948, 160 pp.

21. Dikkers, Robert, "Steam and Boiler Size Requirements for Curing Systems," National Concrete Masonry Association, 1958.

22. Eckaus, Richard S., 1977, "Appropriate Technologies for Developing Countries," Massachusetts Institute of Technology, Washington, D.C.

23. "Effect of Mixing Time and Overload on Concrete Produced by Stationary Mixers," Highway Research Board, Bulletin 295, Washington D.C., 1961.

24. Ehle, J.C., "Developments in the Manufacture and Technology of Concrete Masonry Units," ACI Journal, Proceedings V. 45, No. 8, Apr. 1949, 613 pp.

25. "Evaluation Tests of a Concrete Mixer of the Turbine Type," U.S. Army Engineer Waterways Experiment Station, Corps of Engineers. Techn. Rep. No. 6-525, October. Vicksburg, Mississippi, 1959.

26. Gadgil, D.R., "A note on Intermediate Technology," Small Industry Extension Training Institute, Hyderabad, 1964.

27. Gaynor, R.D., "Effects of Prolonged Mixing on the Properties of Concrete," National Ready Mix Concrete Association, Publication No. 111, June, Washington, D.C., 1963.

28. Grant, W., "Kilns," Concrete, Vol. 64, No. 12, Dec. 56, pp. 31-34.

29. Grant, W., "Manufacturing of Concrete Masonry Units-9," July 1951, 30 pp.

30. Gross, M.H., "Modern Curing of Concrete Block," Pit and Quarry, Vol. 45, No. 9, (March 1956), pp. 223-226.

31. Hammond, Ross W., "Appropriate Technology Research at Georgia Tech and the Small Industry Development Network," Georgia Institute of Technology, Atlanta.

32. Hanson, J.A., "Optimum Steam Curing Procedure in Precasting Plants," ACI Journal, Proceedings V. 60, No. 1, Jan. 1963, pp. 75-100.

33. Higginson, E.C., "Effect of Steam Curing on the Important Properties of Concrete," ACI Journal, Proceedings V. 58, No. 3, Sept. 1961, pp. 281-298.

34. Johansson, Arne, 1933, "The Relationship Between Mixing Time and Type of Concrete Mixer," Stockholm, Cement och betonginstitut, 1971.

35. Johnson Gas Appliance Company, Engineering Bulletin for: Johnson Direct Fired Steam Curing System; Johnson Direct Fired Drying System; Johnson Autocure System.

36. Kalousek, George L.; O'Heir, Richard J.; Zeims, Kenneth L.; and Saxer, Edwin L., "Relation of Shrinkage to Moisture Content in Concrete Block," ACI Journal, Proceedings V. 50, No. 3, Nov. 1953, pp. 225-240.

37. Kirkham, R.H.H., "Performance of Plant for Mixing and Placing Concrete; Batching, Mixing, and Handling," The Reinforced Concrete Association, Structural Concrete, 5, Year 1, London, 1962, pp. 205-217.

38. Klieger, Paul, "Effect of Mixing and Curing Temperature on Concrete Strength," Research Department Bulletin 103, Research and Development Laboratories, Portland Cement Association, Skikie, Ill., 1958.

39. Klieger, Paul, "Effect of Mixing and Curing Temperature on Concrete Strength," ACI Journal, Proceedings V. 54, No. 12, June 1958, pp. 1063-1082. Also Research Department Bulletin 103, Portland Cement Association.

40. Kluge, R.W.,; Sparks, M.M.; and Tuma, E.C., "Lightweight-Aggregate Concrete," ACI Journal, Proceedings V. 45, No. 9, May 1949, pp. 625-644.

41. Kuenning, W.H., and Carlson, C.C., "Effect of Variations in Curing and Drying on the Physical Properties of Concrete Masonry Units," Development Department Bulletin D-13, Research and Development Laboratories, Portland Cement Association, Skikie, Ill., 1956.

42. Lovewell, C.E., and Washa, George W., "Proportioning Concrete Mixtures Using Fly Ash," ACI Journal, Proceedings V. 54, No. 12, June 1958, pp. 1093-1101.

43. Mangotich, E., "Some Tests of the Compressive Strength of Concrete Masonry Units as Affected by the Time-Temperature Maturity with Curing at Atmospheric Pressure," Technical Report No. 47, National Concrete Masonry Association, Washington, D.C., May 1954.

44. Mansfield, G.A., "Curing--A Problem in Thermodynamics," Rock Products, V. 51, No. 8, Aug. 1948, pp. 212.

45. Marsden, Keith, 1970, "Progressive Technologies for Developing Countries," International Labour Review, Vol. 101, No. 5, May.

46. Mathews, H.L., "Prefabricated Pumice Concrete Houses," ACI Journal, Proceedings V. 44, No. 9, May 1948, pp. 797.

47. Matz, Adolph, and Othel J. Curry, "Cost Accounting Planning and Control," South-Western Publishing Co., 1972.

48. Maynard, H.B., "Industrial Engineering Handbook," Third Edition, McGraw-Hill.

49. Mchedlov-Petrosyan, O.P., "Influences of New Knowledge of Cement Chemistry on the Improvement of the Quality of Concrete," Hochschule fur Bauwesen, Peipzig, 1963, pp. 9-10.

50. Menzel, Carl A., "Autoclaving in the United States--A Progress Report," Concrete Products, V. 63, No. 5, May 1960, pp. 24-31.

51. Mironov, S.A., and Malinina, L. A., "Autoclave Cured Concrete," State Publishing Office of Literature of Structural Engineering Architecture, and Structural Materials, Moscow, 1958.

52. Minor, C.E., "Effects of Mixing Time, Batch Weights on Quality of Paving Concrete," Pacific Builder and Engineer, June, 1954, pp. 92-94.

53. Menzel, C.A., "Studies of High-Pressure Steam Curing of Tamped Hollow Concrete Block," ACI Journal, Proceedings, V. 32, No. 1, Sept.-Oct. 1935, pp. 51-64.

54. Mironov, S.A., "Some Generalizations in Theory and Technology of Acceleration of Concrete Hardening," Proceedings, RILEM Symposium (Moscow, 1964), RILEM, Paris, Session II/16, 29 pp.

55. Nurse, R.W., "Steam Curing of Concrete," Magazine of Concrete Research (London), V. 1, No. 2, June 1949, pp. 127-140.

56. Okita, Saburo, 1961, "Choice of Techniques," Industrialization and Productivity, Bulletin No. 4, United Nations, New York, April.

57. Olson, O.N., "Report of Test of Effects of Some Admixtures on Physical Properties of Concrete Masonry Units," Technical Report No. 22, National Concrete Masonry Association, Washington, D.C., 1949.

58. Price, E.R., "Recommended Practice for Atmospheric Pressure Steam Curing of Concrete," (ACI 517-70), American Concrete Institute: Manual of Concrete Practice.

59. "Requirements for Concrete Masonry Construction," National Bureau of Standards Report No. 3079, Jan., 1954.

60. Saemann, J.C.; Warren, C.; and Washa, G.W., "The Effect of Curing on the Properties Affecting Shrinkage Cracking of Concrete Block," ACI Journal, Proceedings V. 51, No. 9, May 1955, pp. 833-852.

61. Saul, A.G.A., "Principles Underlying the Steam Curing of Concrete at Atmospheric Pressure," Magazine of Concrete Research (London), V. 2, No. 6, Mar. 1951, pp. 127-140.

62. Schlie, Theodore W., 1974, "Appropriate Technology: Some Concepts, Some Ideas, and Some Recent Experiences in Africa," East African Journal of Rural Development, July 1974, pp. 77-108.

63. Sheikin, A.E., and Oleinikove, N.I., "Effect of Hydrothermal Treatment and Fineness of Grinding of Cement on the Structure and Properties of Cement Stone," Proceedings, RILEM Symposium (Moscow, 1964), RILEM, Paris, Session I/17, 30 pp.

64. Shideler, J.J., "Manufacture and Use of Lightweight Aggregates for Structural Concrete," Development Department Bulletin D-40, Research and Development Laboratories, Portland Cement Association, Skikie, Ill., Jan. 1961.

65. Shideler, J.J., "Investigation of the Moisture-Volume Stability of Concrete Masonry Units," Development Department Bulletin D-3, Research and Development Laboratories, Portland Cement Association, Skikie, Ill., 1955.

66. Shideler, J.J., "Low Pressure Steam Curing," American Concrete Institute: Manual of Concrete Practice.

67. Shideler, J.J., "Investigation of the Moisture-Volume Stability of Concrete Masonry Units," Development Department Bulletin D-3, Portland Cement Association, Mar. 1955, 54 pp.

68. Shideler, J.J., "Manufacture and Use of Lightweight Aggregates for Structural Concrete," Development Department Bulletin D-40, Portland Cement Association, Jan. 1961, 18 pp.

69. Shideler, J.J., and Chamberlin, W.H., "Early Strength of Concrete as Affected by Steam Curing Procedures," ACI Journal, Proceedings V. 46, No. 4, Dec. 1949, pp. 273-284; See also Report C-456, Material Laboratory, U.S. Bureau of Reclamation.

70. Shore, J.W., "The Design and Engineering of Steam Curing Instalations for Concrete Block Plants," Pit and Quarry, V. 43, Nov. and Dec 1950.

71. Shore, W.J., "How to Build Well Insulated Block Curing Kilns," Concrete Products, V. 57, No. 12, Dec. 1954.

72. "Siporex Lightweight Concrete," The International Siporex Co., Ltd., Stockholm, 1950.

73. Stepanek, Joseph E., "Choice of Industrial Technologies," Small Industry Extension Training Institute, Hyderabad, 1964.

74. Steinour, Harold H., "Concrete Mix Water-How Impure Can It Be?" Journal, Research and Development Laboratories, Portland Cement Association, V. 2, No. 3, Sept. 1960, pp. 32-50.

75. Stepanek, J.E., 1966, "Technologies Appropriate for Industry in the Developing Countries," United Nations Center for Industrial Development, STD/5/RPCA/IND/1, 9 March.

76. Staley, Eugene, and Richard Morse, "Modern Small Industry for Developing Countries," New York: McGraw-Hill, 1965.

77. "Summary of NCMA Curing Tests," Technical Report No. 13, National Concrete Masonry Association, Washington, D.C., July 1947.

78. Taylor, H.F.W., The Chemistry of Cements, Academic Press, London, 1964, 460 pp.

79. "Technical Report No. 40," National Concrete Masonry Association, Chicago, Jan. 19, 1953.

80. Toennies, H.T., "Artificial Carbonation of Concrete Masonry Units," ACI Journal, Proceedings V. 56, No. 8, Feb. 1960, pp. 737-756.

81. United Nations, 1972, "Appropriate Technology and Research for Industrial Development," ST/ECA/i52, New York.

82. Valore, R.C., Jr., and Green, W.C., "Air Replaces Sand in 'No Fines' Concrete," ACI Journal, Proceedings v. 47, No. 10, June 1951, pp. 833-848.

83. Valore, R.C., Jr., "Insulating Concretes," ACI Journal, Proceedings V. 53, No. 5, Nov. 1956, pp. 509-532.

84. Verbeck, G.J., "Carbonation of Hydrated Portland Cement," Research Department Bulletin 87, Research and Development Laboratories, Portland Cement Association, Skikie, Ill., 1958.

85. Weddell, Kennard, 1968, "Promotion of Small Scale Industries Through Government Purchasing," Industrialization and Productivity, Bulletin No. 12, United Nations, New York.

86. Wendt, K.F., and Woodworth, P.M., "Test on Concrete Masonry Units Using Tamping and Vibration Molding Methods," ACI Journal, Proceedings V. 36, No. 2, Nov. 1939, pp. 121-164.

87. Wilk, B., and Mansfield, G.A., "Some Tests of the Effect of Curing Conditions on Strength of Concrete Block," Technical Report No. 39, National Concrete Masonry Association, Washington, D.C., Jan. 1953.

88. Williams, G.M., "Admixtures and Workability of Concrete," ACI Journal, Proceedings V. 27, Feb. 1931, pp. 647-653.

89. Withey, N.H., "Use of Fly Ash in Block Mixes," Technical Report No. 56, National Concrete Masonry Association, 1956.

90. Wu Chung-Wei, "Presteaming and Temperature-Rise Periods of Low-Pressure Steam Curing of Mortar and Concrete," Research Institute of Building Materials, Peking, 1964, 17 pp.

91. ________, 1963, "Adaptation of Processes, Equipment and Products," Industrialization and Productivity, Bulletin No. 6, United Nations, New York.

92. ________, 1964, "Choice of Capital Intensity in Industrial Planning," Industrialization and Productivity, Bulletin No. 7, United Nations, New York.